



Environmental Remediation Group

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**RE: Comprehensive Data Gaps Work Plan
Olin Chemical Superfund Site – Wilmington, MA**

Dear Ms. Jennings:

Consistent with USEPA's letter of April 17, 2019 and Olin's response of April 26, 2019, we are submitting herewith a Comprehensive Data Gaps Work Plan for the Olin Chemical Superfund Site in Wilmington, MA. The Plan is intended to provide a scope of work to initiate those activities necessary to resolve site-wide data gaps. Tentative scopes are also included for future phases that will be dependent on the results of the first phase of work. We believe the scope to be consistent with discussions held between USEPA and Olin during, and subsequent to, a meeting on June 26, 2019.

Please contact me should you have any questions regarding the information contained herein.

Sincerely,

A handwritten signature in black ink, consisting of a stylized 'J' followed by a horizontal line.

James M. Cashwell
Director, Environmental Remediation

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Data Gaps Work Plan

Prepared for:

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Executive Summary

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This Data Gaps Work Plan (DGWP) has been prepared for the United States Environmental Protection Agency (USEPA) on behalf of Olin Corporation (Olin) for the Olin Chemical Superfund Site (Site) in Wilmington, Massachusetts. The work plan addresses the USEPA comments dated September 25, 2018 (USEPA 2018a), and encompasses the items discussed in the June 26, 2019 meeting with Olin and USEPA in Boston and other communications received to-date. The primary objectives for the DGWP are to identify the data gaps, associated data quality objectives (DQOs), and to define the work phases and schedule required to address the data gaps. The scopes of work have been divided into three Phases with this DGWP focused on Phase I. Scopes of work associated with Phases II and III are also presented herein, but these approximated scopes will be subject to verification pending the results of each preceding phase.

This work plan has been developed in consultation with USEPA and the data gaps which have been discussed are organized by type and Site area. There are six Site areas that include:

1. The Containment Area (CA);
2. Jewel Drive Area;
3. Main Street Area;
4. Maple Meadow Brook (MMB);
5. North of Olin Area; and
6. East of Olin Area.

The DGWP has been developed using a systematic planning process to identify the problem that requires study (data gap). The data gaps will be overcome through the data collection activity, understanding of the spatial scale of the data needed, identification of methods meeting data collection goals and specification of performance criteria and/or accuracy.

The DGWP presents a phased approach for data collection, allowing iterative refinements to subsequent tasks after initial data collection activities are completed (Table 1). Phase I

includes comprehensive seismic reflection surveys to address the bedrock surface data gap(s). In addition, the Phase I work includes:

- In the MMB area, an aerial electromagnetic (AEM) survey will be conducted to further characterize the bedrock topography and identify areas of higher conductivity groundwater;
- In the northern portion of the Olin property and the off-Property groundwater areas to the north, preliminary direct push soil and groundwater sampling will be completed to address the extent and distribution of NDMA impacts. Synoptic groundwater levels will also be collected in the area of interest;
- A monitoring well cluster replacement for a previously damaged/destroyed well (GW-26); and
- Installation of surface water gauges.

The results of the Phase I work will be discussed with the USEPA, after which a Phase I report and a Phase II work plan will be developed. Phase II is currently anticipated to consist of locating and drilling confirmatory borings and monitoring well installations (Table 1) across the Site/study area(s). The results of the Phase II data collection will be discussed with the USEPA, after which a Phase II report and a Phase III work plan will be developed. At each stage, the Conceptual Site Model (CSM) will be updated to guide decisions/work for the following phases.



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- A USEPA comment response matrix tables A-1 through A-8.**
- B Standard Operation Procedures for Seismic Reflection Survey**
- C Outline of Standard Operation Procedures for AEM survey**
- D Technical approach for drilling, sampling, logging, construction and development of wells (Addendum IV to the Final RI/FS Work Plan)**
- E Field Sampling Plan for the direct push soil and groundwater sampling**
- F Standard Operation Procedures (SOPs)**
- G Quality Assurance Project Plan (QAPP)**
- H Site Management Plan (SMP), Community Relations Support Plan (CRSP) and Health and Safety Plan (HASP)**

Tables

- 1 Summary Table of Data Gaps Work Plan
- 2 Compendium of Identified Data Gaps and Associated Activities.

Figures

- 1 The Wilmington OCSS Site identifying primary USEPA Data Gap Areas.
- 2 Conceptual site model describing the distribution of geologic materials in conjunction with groundwater and DAPL elevation.
- 3 Containment area showing proposed seismic lines and tentative confirmatory/monitoring wells.
- 4 Jewel Drive (OPWD) area showing proposed seismic lines and tentative confirmatory/monitoring wells.
- 5 Main Street area showing proposed seismic lines. At least 12 monitoring wells will be installed at tentative boring locations during Phase II.
- 6 Extent of the potential AEM study area in the Maple Meadow Brook area, with existing seismic lines and bedrock monitoring well locations.
- 7 North of Olin (GW-413 area) showing proposed seismic lines, direct push sampling, and tentative geophysics/monitoring wells in relation to the NDMA plume (After Wood 2018a & b). Inset shows proposed soil bore locations around the former Plant B production area.
- 8 East-of-Olin area showing proposed seismic reflection lines and tentative geophysics/monitoring wells.
- 9 Existing and proposed surface water gauging locations.
- 10 Gantt Chart for Phase I of the Data Gaps Work Plan.

Acronyms and Abbreviations

°	degrees
AEM	Airborne Electromagnetic
ATV	Acoustic Televiewer
bgs	below ground surface
BRD	deep bedrock
BRS	shallow bedrock
CA	Containment Area
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
COC	constituent of concern
CRSP	Community Relations Support Plan
CSM	Conceptual Site Model
D	deep overburden
DAPL	dense aqueous phase liquid
DGWP	Data Gaps Work Plan
DQO	Data Quality Objectives
EM	electromagnetic
FS	Feasibility Study
FSP	Field Sampling Plan
ft	feet
gpm	gallons per minute
GPS	global positioning system
HASP	Health and Safety Plan
HPFM	Heat-pulse Flowmeter
IDW	Investigative derived waste
MMB	Maple Meadow Brook
NDMA	N-Nitrosodimethylamine
Olin	Olin Corporation
OPWD	Off-Property West Ditch
OTV	Optical Televiewer
OU3	operational unit 3
Q	Quarter
QAPP	Quality Assurance Project Plan
QA/QC	quality assurance/quality control
R	Resistivity
RI	Remedial Investigation
S	shallow overburden
Site	Olin Chemical Superfund Site
SMP	Site Management Plan
SOP	Standard Operating Procedure

SOW	statement of work
SP	Spontaneous Potential
SPF	slots per foot
TIE	Technical Impracticability Evaluation
USEPA	United States Environmental Protection Agency



Text

1 Introduction

The USEPA and Olin have been in communication regarding data gaps for several areas across the Site/study area following Olin's submittal of the March 30, 2018 Draft Operable Unit 1, 2, & 3 Remedial Investigations and Feasibility Studies (RI/FS) (Amec 2018a, b, & c). The USEPA identified several data gaps in its comments to Olin's RI/FS submittal, dated September 25, 2018 (USEPA 2018a). This work plan addresses these comments along with other communications received to date. On April 17, 2019, the USEPA provided a letter (USEPA 2019a) requiring Olin to submit a Data Gaps Work Plan (DGWP) to address the Site and meet the objectives of the RI/FS.

On June 26, 2019, the USEPA and Olin participated in a meeting to address each data gap and agree on a tentative scope-of-work (pending USEPA approval of this work plan). This document identifies the data gaps and provides a comprehensive work plan to address them in a phased approach consistent with the June 26, 2019 meeting.

The primary objective for the DGWP is to refine and complete the Conceptual Site Model (CSM) with consensus from both USEPA and Olin. Currently, several data gaps exist that require closure to fully define the CSM. This DGWP addresses the data collection necessary to resolve those gaps.

The work has been divided into three Phases to allow for iterative data collection, followed by USEPA and Olin review to obtain consensus on the next set of activities. The purpose of this DGWP is to present the combined EPA and Olin approach for the Phase I scope. The potential scope of the work plans for Phases II and III are summarized in this document, but are subject to updates and revisions based on the results and comments received from EPA after each preceding Phase. As agreed during the June 26 meeting, Phase II proposed borings would be limited to indicating a range of boring numbers within this Phase I DGWP.

1.1 Site Background

The majority of the work described in this DGWP is widely recognized/utilized across the industry and has been undertaken on the Site over the past 25+ years. The site background has been described thoroughly in several previous documents submitted by Olin (e.g., AMEC

2014, 2018c; Wood 2019a). These documents contain detailed information on the background hydrogeology and CSM, and are meant to be primary sources of information on the Site. The DQOs associated with each data gap are discussed in Section 2.2, and also contain summaries of background information and relevant CSM.

1.2 Work Plan Organization

Section 2 provides a brief overview of the underlying data gaps. Section 3 describes the scope of work to address the data gaps specific to the seven Site areas, and Section 4 provides a preliminary schedule for the work plan Phases. It should be noted that the schedule presented herein is contingent on USEPA approval of the work scope and acquisition of access agreements where appropriate.

Documentation for the majority of the field activities described in this work plan has been established in accordance with the RI/FS work plans, so the Standard Operating Procedures (SOPs) and the Quality Assurance Project Plan (QAPP; Wood 2019b) for field work and data collection are attached to, and referenced in this document for ease of access.

2 Data Gaps Identification

This document addresses each pertinent data gap comment received from the USEPA (USEPA 2018a, b, & c; 2019a, b, & c) since the Draft RI/FS reports were submitted in March 2018. Based on review of comments and responses for the above referenced documents, there are three major classes of data gaps identified by the USEPA and Olin:

1. Bedrock characterization – bedrock surface topography and fractures;
2. The extent, source, and fate of the N-Nitrosodimethylamine (NDMA) plume and other site constituents of concern (COCs); and
3. DAPL pool characterization – presence within the overburden, weathered bedrock, and competent and fractured bedrock.

The site contains six areas where a combination of these data gaps exists (Figure 1):

1. Containment Area (CA) – bedrock and DAPL pool characterization.
2. Jewel Drive (Off-Property West Ditch [OPWD]) – bedrock and DAPL pool characterization.
3. Main Street – bedrock and DAPL pool characterization.
4. MMB – bedrock and DAPL pool characterization/ NDMA plume extent.
5. Area North of Olin – bedrock characterization, and the extent, source and fate of the NDMA plume and other site COCs.
6. Area East of Olin – bedrock characterization, and the extent of the NDMA plume and other site COCs.

On a site-wide basis all of the above areas will be assessed for bedrock fracture connectivity, surface/groundwater interactions and DAPL diffuse layer cutoff measurements. As discussed in the June 26, 2019 meeting with Olin and USEPA, soils within the CA will be addressed in a separate plan, which was submitted on July 26, 2019. The following sections describe the details behind each of the major data gap classes. Section 2.1 reviews the background documentation for the identification of the data gaps and Section 2.2 lists the associated DQOs.

2.1 Supporting Documents for Identification of Data Gaps

All of the data gaps identified in this document were partly derived from documents submitted by the USEPA and Olin (and their subcontractors) over an approximately 1-year time frame. Data gap information has also been gathered from meetings and communication between the USEPA and Olin. The majority of the data gap material is in USEPA's Notice of Disapproval letter sent September 25, 2018 (USEPA 2018a) as described more thoroughly below

2.1.1 Data Gap Tables

The attached tables summarize the proposed work plan elements, and list the data gaps identified in comments, letters, and memos submitted by the USEPA and Olin. Table 2 provides an outline of each data gap major class, associated Site area, Phase schedule, general DQOs, and scope of work to address the data gaps. As stated above, a more detailed description of the DQOs for the data gaps is discussed in Section 2.2. Appendix A contains eight tables listing the data gaps associated with comments and responses that the USEPA has submitted to Olin.

2.2 Data Gap Descriptions and Data Quality Objectives

Olin and USEPA have worked collaboratively to identify the data needs and gaps based on stated goals for each data collection activity that considers the spatial scale of the Site area. The following sections describe the overall data gaps associated with the major classes referenced above, and their associated DQOs.

2.2.1 Bedrock Characterization Data Gap

The DQOs for the bedrock characterization data gaps described in this section follows the relevant USEPA guidance (USEPA 2006), and are meant to serve as a guide for the data collection work plan (Section 3).

The bedrock surface topography has been characterized using data ranging from seismic reflection and refraction surveys, to confirmatory borings and geophysical logging of the bedrock on a borehole scale (e.g., Figure 2). The existing data and the interpreted bedrock surface are presented in the figures focused on each Site area (Figures 3 through 8). Data

gaps have been identified in key areas, particularly related to the distribution of the DAPL pools in the subsurface. The important elements of the bedrock characterization data gaps include:

- The bedrock topography, including both saddle areas and the basal configuration,
- Bedrock fracture orientations, frequency, and interconnectivity at the borehole scale, and
- The nature of contaminant transport within the bedrock formation.

The data to be generated in the proposed phased approach (as detailed in this work plan) is necessary to inform/refine the CSM for the Site, and provide a better understanding of fracture distribution and groundwater flow in the bedrock. In addition, the bedrock characterization data will inform/depict a robust 3-D model of the bedrock topography and fracture networks. The model will refine the basis for the CSM, DAPL volume calculations, a future Technical Impracticability Evaluation (TIE), and the anticipated remedial design work.

2.2.1.1 Problem Statement

The current configuration of the bedrock surface has uncertainty between areas of known data (seismic data and/or well boring data), or requires additional confirmatory information. In particular, where the DAPL pool is present in the Main Street area, there are questions regarding how best to interpret the presence of small multiple depressions indicated by current data, and the continuity of larger scale bedrock topographic features controlling the movement of DAPL (e.g, saddles, valleys, and ridges). Also, information on the orientation and frequency of water-bearing fractures within the bedrock would benefit from additional characterization, particularly beneath and adjacent to DAPL pools. Characterization of fracture networks capable of transmitting DAPL and/or diffuse groundwater is required to refine the CSM and select the remedy for the Site.

The historic CSM consists of an aquifer within unconsolidated glacial sedimentary deposits (overburden) underlain by an undulating gneissic bedrock surface with varying degrees of weathering, folding, and fracturing. Pools of DAPL have settled into depressions within the

bedrock, and contaminants diffuse from the DAPL layer into the overlying groundwater within the overburden, forming plumes migrating with the regional groundwater flow system, generally following the direction of the groundwater flow within adjoining watersheds. The Ipswich watershed flows to the west and north through the Maple Meadow Brook area, and to the north of the Olin property. The Aberjona watershed flows to the east and south. The groundwater divide (generally located at the boundary between the two watersheds) fluctuates seasonally at the groundwater high measured on the Olin property, to the west aligned approximately with Eames Street, and to the south along Main Street (Wood 2019c).

A DAPL pool is located within the Olin property within the CA. On its western side, a portion of the CA slurry wall is in contact with DAPL. Adjacent to the CA to the west is the Jewel Drive (OPWD) DAPL pool, and further to the west, following the slope of the bedrock is the Main Street DAPL pool (Figure 1 and Figure 2). DAPL has been identified in one deep monitoring well (GW-83D) that is screened across overburden and weathered bedrock within the MMB, where elevated levels of NDMA and specific conductance persist.

In their comments, the USEPA has presented several important questions related to the accuracy of the historical CSM. These questions served to identify data gaps for each of the Site areas. The USEPA has pointed to uncertainty in estimated bedrock elevations, and the potential for alternative configurations (USEPA 2018c; 2019b). The USEPA has also requested assessment of the potential for fractures to transport DAPL and/or diffuse groundwater through bedrock features originally conceptualized as barriers to flow. These differences are addressed within the DQOs for each data gap. Details behind the USEPA's CSM questions and the associated data gaps as well as Olin's comments and responses are outlined in Appendix A.

The types of data required to resolve the requests described above consist of quantifying the top of the bedrock surface elevation and hydraulically active, water-bearing fracture frequency, orientation, and distribution. Phase I work, generally, but not exclusively, involves seismic reflection and AEM surveys, which will provide the necessary initial information to evaluate and confirm the current understanding of the bedrock surface

topography and potentially larger scale water-bearing fractures. Confirmatory borings (into bedrock) will validate the depth to the top of bedrock interpreted from the seismic data. The bedrock surface and fracture information will refine the 3D model of the bedrock surface and fractures, which will be used as a guide for decisions to locate the necessary confirmatory/monitoring wells in Phase II of the work plan.

Phase II confirmatory borings will be advanced a minimum of 10 feet into the bedrock to confirm the bedrock surface elevation estimated from the seismic reflection data. Detailed logging of the deeper bedrock bores will provide information on bedrock lithology and fracture frequency/orientation. Straddle packer testing and sampling within the boring will provide information on flow potential within discrete intervals of fractured vs. competent bedrock.

2.2.1.2 Study Goals

The study goals for the Phase I bedrock characterization data gap work are to, 1) validate and refine the existing bedrock surface and fracture data, 2) obtain bedrock characterization data in areas where little to no information exists, 3) update the 3-D model and CSM (topography and hydrogeology) for the bedrock surface, formation, and fracture networks, and 4) optimize the locations for Phase II confirmatory borings and monitoring well installations.

The principal questions to be answered for the bedrock characterization work are:

- What is the overall bedrock surface topography and where are there bedrock depressions within and adjacent to the DAPL footprints?
- Are there fractures within and adjacent to the DAPL footprints that are capable of storing and/or transmitting contaminated groundwater or DAPL?
- What are the most practical and informative locations for confirmatory borings/monitoring wells?

Seismic reflection surveys coupled with confirmatory borings have been demonstrated in past studies for the Site to be a reliable method to define the top of the bedrock surface beneath the overburden. AEM surveys are also a reliable method to estimate surfaces of contrasting properties. Contouring the bedrock surface topography will depict the shape and

slope of depressions, and ridges/valleys, and will provide an interface to discuss and identify ideal locations for confirmatory borings/monitoring wells. In addition, 3D visual mapping of the bedrock surface and the projection of fracture networks and their potential interconnectivity will help update the CSM for the Site, and further inform/refine the locations for confirmatory borings/monitoring wells.

The use of different existing and proposed technologies has been considered to address the bedrock characterization data gap:

- **Additional seismic reflection lines.** Once the initial data sets have been collected, some subsurface features may indicate the need for a more refined data set. Additional seismic reflection lines with closer spacing may be required to address any areas of uncertainty.
- **Seismic refraction surveying.** During discussions between USEPA and Olin, the collective teams agreed that seismic refraction data may not be as reliable as seismic reflection data, but it does provide information on the depth to the top of bedrock. So, the historical information will be incorporated judiciously in the verification process.
- **Airborne or ground-based electromagnetic survey.** The MMB area and some portions of the CA are the only areas accessible for the AEM survey, due to the close proximity of residential areas, buildings, power lines, fences, etc. The inaccessible nature of the MMB swamp poses significant Health and Safety concerns for drilling or land-based data collection operations. Groundwater wells were installed in the past when the Town wells were actively depressing the water table, which drained the surface water features and swamp. Without the Town wells pumping, the surface water has risen and rendered access to the MMB difficult and potentially dangerous.

The Phase I bedrock characterization data gap work will collect information to estimate the overburden thickness, weathered bedrock thickness, depth to competent bedrock (based on the rock quality description of a geologist), and depth and orientation of bedrock fractures.

The important problems/questions to consider when estimating these parameters are:

- Where is the top of weathered versus competent bedrock (along with a range of uncertainty) at any particular location?
- Does the weathered bedrock behave as a distinct hydrostratigraphic unit?
- What are the expected frequencies and orientations of water-bearing fractures within the bedrock (at depth up to ~100 ft below top of bedrock surface)?

- What type of rock is expected to be identified when coring into competent versus weathered bedrock?
 - Can the bedrock lithology be distinguished from cobbles or glacial erratics which may be false indicators of the bedrock surface?

2.2.1.3 Information Inputs

The main information to be collected from the Phase I bedrock characterization data gap work consists of depth to the top of competent bedrock. The existing data on depth to bedrock for the site consists of past seismic reflection and refraction surveys, and boring data (Figures 3 through 8). The existing data will help constrain the estimation of the depth to the top of bedrock for both the seismic reflection and AEM survey techniques.

Seismic reflection data clearly defines a contrast in pressure velocity when the bedrock surface is encountered, allowing depths to be estimated. In addition, bedrock fractures can produce a reflection signal providing information to estimate the strike and dip of the fracture plane or the presence of larger fractures or faults where displacements may have occurred.

AEM data consists of conductivity measurements received from transmission of multiple frequencies where lower electromagnetic (EM) frequencies penetrate deeper into the subsurface. Similar to seismic reflection, changes and contrasts in measured EM frequencies that are transmitted into the subsurface can reveal surfaces of significant lithologic changes. Existing seismic and boring data that inform the layered earth model will be used to improve the estimation of the depth to overburden/bedrock contacts.

The information for the Phase II work will be updated and revised based on the results of Phase I, but are expected to include, 1) updated bedrock surface topography, 2) bedrock coring, 3) logging data for boreholes completed in the bedrock (e.g., caliper, acoustic, Spontaneous Potential [SP], Resistivity [R], Temperature, Conductivity, Optical Televiewer [OTV]/ Acoustic Televiewer [ATV], and Heat-pulse Flowmeter [HPFM]), 4) orientation (strike and dip) and frequency of water-bearing fractures, and 5) flow characteristics (specific capacity, hydraulic conductivity) for fractured and competent bedrock. Drilling logs can reliably indicate when a difference in material substance is encountered, and cores will be collected to verify that the bedrock surface has been encountered. Detailed bedrock borehole

geophysical logging will determine the presence and orientation of bedrock fractures and their potential to store and transmit water.

Existing information and data collected for the bedrock surface geometry will be used to enhance the resolution of the seismic and AEM data interpretation. The current estimates of data resolution for the bedrock characterization data are:

- Seismic reflection data
 - Depth to bedrock surface within ~1-5 ft (errors are site-specific), to be determined based on available borings.
- AEM survey data
 - The accuracy of depth to bedrock surface is depth dependent (e.g., ~10% error at 100 ft (or greater) depth; ~5% error at 30 ft depth, also depending on resistivity contrasts in material type).
 - Width resolution is depth dependent, but ~10 ft accuracy for shallow depths.
- Top-of-bedrock variability between geophysics and coring ± 2 ft.
- Geophysically-logged features within 0.1 ft.
- Flow measurements within 0.01 gpm.
- Depth to groundwater measurements within 0.01 ft.

There are three variables that will be measured in the field for the seismic reflection survey.

1. Seismic line distance
2. Geophone spacing
3. Seismic traces vs. time

2.2.1.3.1 Seismic Reflection Survey Components

The seismic reflection survey work consists of laying out a series of geophones which collect subsurface pressure wave data from transmitted pulses (or “shots”) of energy (e.g., hammer on steel plate in contact with the ground). The raw data consists of measured pressure waves interpreted as velocity within the subsurface. Depth to bedrock is estimated from time and

velocity of measurement. Breaks in pressure waves indicate a change in velocity, thus a change in material type. These data are entered into a computer program using known Site information to model and constrain the depth estimations where changes in pressure waves are evaluated (Appendix B).

2.2.1.3.2 AEM Survey Components

There are three variables that will be measured in the field for the AEM survey.

1. Electromagnetic data
2. Magnetic data
3. Global Positioning System (GPS) data (x, y, z) with time

The AEM survey consists of flying a large dipole instrument (EM transmitter and receiver AirTEM® system), which hangs from a helicopter ~100 feet above the land surface (Appendix C). The system is approximately 9 m in diameter with 7 turns of aluminum transmitter wire and a peak transmitter current of 375-400 A for a total dipole moment of 150,000 to 160,000 Am² (depending on available helicopter power). EM pluses are transmitted and received from the instrument every 10 microseconds, along with the altitude and flight path measurements of the instrument using a GPS. Data is acquired using a fully differential, real-time GPS receiver. This produces a series of time profiles, each with a unique (x,y,z) position that when converted to conductivity-depth images (CDIs), allows modeling and visualization in 3-D. Differences in conductivity/resistivity coupled with existing information are interpreted as changes in the subsurface material and referenced by the expected lithologic and geochemical properties.

2.2.1.3.3 Borings and Borehole Logging Components

The Phase II confirmatory/monitoring well borings will be drilled using a sonic drill rig (or equivalent), capable of collecting core samples that will identify the weathered/competent bedrock interface. Drilling refusal due to boulders vs. bedrock will be interpreted based on the lithology of the core samples. Boring at least 10 ft into the bedrock will confirm intersection of the bedrock surface.

There are six variables that will be recorded in the field log for the borehole drilling:

1. Lithology/soil classification
2. Depth to groundwater
3. Depth to top of weathered bedrock
4. Depth to top of competent bedrock
5. Core sample interval/recovery
6. Observation of fractures

There are 13 variables that will be measured in the field for the borehole geophysical logging and other borehole testing:

1. Depth to top of competent bedrock as described above
2. Depth to water-bearing bedrock fractures
3. Strike and dip of water-bearing bedrock fractures
4. Aperture of water-bearing bedrock fractures
5. Competent vs. fractured bedrock flow characteristics (flow rate and head measurements from borehole testing)
6. Caliper measurements
7. Spontaneous Potential (SP)
8. Resistivity
9. Temperature
10. Conductivity
11. Optical Televiewer (OTV)
12. Acoustic Televiewer (ATV), and

13. Heat-pulse Flowmeter (HPFM)

Phase II borehole logging, sampling and flow testing of bedrock formations will be completed using a variety of downhole instruments and methodology (Appendix F), with additional details to be provided in the Phase II work plan.

2.2.1.4 Study Area Boundaries

The boundaries for the bedrock characterization data gap work are identified on the maps for each Site area (Figures 3 through 8). The number and anticipated lengths of seismic lines, area and boundary for the AEM survey, locations and anticipated depths for Phase II confirmatory borings and monitoring well installations, etc. are depicted on the map figures and detailed below. The seismic lines have purposefully been located perpendicular to, and in alignment with the inferred bedrock fracture orientations previously mapped by the USEPA.

2.2.1.4.1 Containment Area (CA)

The primary target areas for the seismic work in the CA are the bedrock depression(s) inside the slurry wall and potential steeply-dipping bedrock fractures (orientations depicted on Figure 3). The CA seismic reflection survey work consists of 9 lines with ~5-ft geophone spacing (Figure 3):

1. Oriented NE-SW across the NW corner of the CA, ~420 ft, ~84 geophones,
2. Oriented NE-SW across the western portion of the CA, ~650 ft, ~130 geophones,
3. Oriented NE-SW across the width of the CA, ~680 ft, ~136 geophones,
4. Oriented NE-SW across the eastern portion of the CA, ~470 ft, ~94 geophones,
5. Oriented NW-SE across the northern portion of the CA, ~680 ft, ~136 geophones,
6. Oriented NW-SE across the width of the CA, ~820 ft, ~164 geophones,
7. Oriented NW-SE across the southern portion of the CA, ~670 ft, ~134 geophones,
8. Oriented NW-SE across the southwestern portion of the CA, ~420 ft, ~84 geophones.
9. Oriented NW-SE across the SW corner of the CA, ~350 ft, ~70 geophones.

Additional seismic lines will be considered for the Phase II work plan, if and as relevant, following review of the results of the Phase I work. For example, an assessment of the bedrock surface beneath the slurry wall (Brandon 2019) may need further seismic evaluation depending on Phase I results. Containment Area Phase II confirmatory borings/monitoring well locations will be determined following the results of the seismic reflection data interpretation. As discussed with USEPA, this effort could range from four to 10 confirmatory borings completed ~10 ft into bedrock to confirm the seismically interpreted bedrock surface. At least four and possibly more of the confirmatory boring locations are currently anticipated to be advanced up to ~100 ft into the bedrock (below the confirmed top of bedrock surface), and monitoring well clusters will be installed in the: 1) shallow overburden (S) ~10-20 ft bgs, 2) deep overburden (D) ~0-10 ft above top of bedrock, 3) shallow bedrock (BRS) ~20 ft below top of bedrock, and 4) deep bedrock (BRD) ~100 ft below top of bedrock. To the extent possible, bedrock confirmations borings that can be completed as monitoring wells will be identified in the Phase II work plan in order to make the drilling program as cost-effective as possible by avoiding, where possible, duplication of boring locations.

2.2.1.4.2 Jewel Drive (OPWD) Area

The primary target area for the seismic work in the Jewel Drive area is the bedrock depression where DAPL has been characterized directly beneath the on-property building. Also of importance is targeting any steeply-dipping bedrock fractures with orientations as depicted on Figure 4. The Jewel Dr. seismic reflection survey work consists of 6 lines with ~5-ft geophone spacing (Figure 4):

1. Oriented N-S parallel to Jewel Dr. across the western edge of the DAPL pool, ~570 ft, ~114 geophones,
2. Oriented N-S across the western portion of the DAPL pool, ~380 ft, ~76 geophones,
3. Oriented N-S across the width of the DAPL pool and extended to the north, ~560 ft, ~112 geophones,
4. Oriented NW-SE across the width of the DAPL pool, ~320 ft, ~64 geophones,
5. Oriented E-W across the width of the DAPL pool terminating at inaccessible areas on the east side, ~380 ft, ~76 geophones,

6. Oriented E-W across the width of the DAPL pool terminating at inaccessible areas on the east side, ~360 ft, ~72 geophones,

One monitoring well (GW-26; Figure 4) will be replaced in the Jewel Drive area during Phase I. Once bedrock is encountered during drilling, cores will be drilled at least 10 ft into the bedrock and evaluated by a field geologist to verify the depth to bedrock. This will provide additional data for the CSM. In addition, an adjacent deep bedrock borehole will be completed and logged to discern between weathered, competent and fractured bedrock. Although the original GW-26 was a shallow driven well point, the replacement will be installed as a well cluster with screens in the shallow and deep overburden and shallow and deep bedrock (e.g., 1) shallow overburden (S) ~10-20 ft bgs, 2) deep overburden (D) ~0-10 ft above top of bedrock, 3) shallow bedrock (BRS) ~20 ft below top of bedrock, and 4) deep bedrock (BRD) ~100 ft below top of bedrock). Additional details on the Phase I monitoring well drilling and installation methods are provided in Section 3.

The Jewel Drive Phase II confirmatory borings/monitoring well locations will be determined following the results of the seismic reflection data interpretation. As discussed with USEPA, this effort could range from 5 to 8 confirmatory borings (completed ~10 ft into bedrock). One confirmatory boring, pending access approval, will be drilled inside the building (located at 8 Jewel Dr.) to confirm the top of bedrock and derived shape of the bedrock depression beneath the building (Figure 4). At least one angled (directional drilling) confirmatory boring east of the building will target the depression beneath the building, if drilling inside the building is unsuccessful. The installation of additional monitoring well clusters will be evaluated following the results of the seismic reflection data interpretation; however, a multiport DAPL monitoring well will be installed on the west side of the building (Figure 4). There will be at least one additional multiport well installed, if needed, following the interpretation of the seismic data.

2.2.1.4.3 Main St. Area

The primary target areas for the Main St. area consist of the:

1. Confirmation of bedrock topography within and in the vicinity of the Main Street DAPL pool area,

2. Bedrock fracture characterization.

Specific details on the data gaps identified for the Main St. area in emails, letters, and presentations are addressed in Appendix A. These included the verification of the bedrock surface topography, identification of water-bearing fractures to understand the potential for transport pathways within the bedrock, and the location of any additional spillways or saddles for DAPL/diffuse groundwater in the transverse bedrock ridge that forms the western side of the DAPL pool. The Phase I Main St. seismic reflection survey work consists of 21 lines with ~5-ft geophone spacing to address these target areas (Figure 5):

1. Oriented NE-SW along the deepest portion of the interpreted bedrock depression in the southern half of the DAPL pool area, ~550 ft, ~110 geophones,
2. Oriented N-S across the width of the DAPL pool and extended to the north, ~1,260 ft, ~252 geophones,
3. Oriented NW-SE across the eastern half of the southern portion of DAPL pool, ~510 ft, ~102 geophones,
4. Oriented NW-SE across the width of the southern portion of the DAPL pool and to the west to incorporate the interpreted bedrock ridge, ~1,070 ft, ~214 geophones,
5. Oriented N-S across the width of the DAPL pool, parallel to Main St. and extended to the north, ~1,360 ft, ~272 geophones,
6. Oriented N-S across the western edge of the DAPL pool and extended to the north to incorporate the interpreted bedrock saddle, ~1,220 ft, ~244 geophones,
7. Oriented NE-SW along the interpreted bedrock ridge and saddle to the west of the DAPL pool, ~1,120 ft, ~224 geophones,
8. Oriented NE-SW across the western portion of the DAPL pool, ~1,090 ft, ~218 geophones,
9. Oriented NE-SW across the interpreted bedrock ridge and the western edge of the DAPL pool, ~880 ft, ~176 geophones,
10. Oriented NW-SE across the interpreted bedrock ridge and the width of the DAPL pool to incorporate the bedrock depressions, ~1,160 ft, ~232 geophones,
11. Oriented NW-SE across the interpreted bedrock saddle and the western portion of the DAPL pool, ~830 ft, ~166 geophones,

12. Oriented W-E across the interpreted bedrock ridge and the northern bedrock depression of the DAPL pool, ~930 ft, ~186 geophones,
13. Oriented W-E across the interpreted bedrock ridge and the northern portion of the DAPL pool, ~1,140 ft, ~228 geophones,
14. Oriented NW-SE across the southern portion of the DAPL pool, ~530 ft, ~106 geophones,
15. Oriented NE-SW across the southeastern portion of the DAPL pool, ~450 ft, ~90 geophones,
16. Oriented NE-SW across the depression to the northwest of the ridge, ~570 ft, ~114 geophones,
17. Oriented NW-SE across the northern edge of the DAPL pool, ~1,380 ft, ~276 geophones,
18. Oriented NW-SE across the northern portion of the DAPL pool and the northern bedrock depression, ~860 ft, ~172 geophones,
19. Oriented NE-SW across the width of the DAPL pool, ~1,020 ft, ~204 geophones,
20. Oriented NW-SE across the southern edge of the DAPL pool, ~790 ft, ~158 geophones,
21. Oriented NE-SW across the northern portion of the DAPL pool, parallel with the bedrock depression, ~330 ft, ~66 geophones.

The Main Street Phase II confirmatory borings/monitoring well locations will be determined following the results of the seismic reflection data interpretation. As discussed with USEPA this effort could range from 15-20 confirmatory borings (completed ~10 ft into bedrock), at least 12 of which will advance up to ~100 ft into the bedrock (below the confirmed top of bedrock surface) where well clusters will be installed in shallow and deep overburden and shallow and deep bedrock. The well clusters to be installed following Phase I will be screened in the, 1) shallow overburden (S) ~10-20 ft bgs, 2) deep overburden (D) ~0-10 ft above top of bedrock, 3) shallow bedrock (BRS) ~20 ft below top of bedrock, and 4) deep bedrock (BRD) ~100 ft below top of bedrock. The need for, and location of additional multiport well installations will be determined following the seismic and confirmatory boring work.

During Phase II, two monitoring wells that have either been destroyed or no longer function properly will be replaced (GW-59 & MP-4; Figure 5). Once bedrock is encountered during drilling, cores will be advanced at least 10 ft into the bedrock to verify the depth to bedrock and provide additional data for the CSM. In addition, the deep bedrock borehole (~100 ft below the bedrock surface) will be geophysically logged to determine the potential for groundwater flow in competent vs. fractured bedrock. GW-59 and MP-4 will be installed as multiport wells, with their locations and sampling port depths contingent on the seismic survey and confirmatory boring results.

Olin has reviewed the memorandum provided by USEPA (Brandon 2019) dated July 11, 2019 as well as the accompanying figures as a follow-on from the referenced meeting. Olin appreciates USEPA's insight and input and intends for the range of confirmatory borings referenced above to be responsive to said memo/figures.

2.2.1.4.4 Maple Meadow Brook (MMB) Area

The primary target area for the AEM survey over the MMB consists of the undeveloped land accessible by helicopter to the west of Main Street. The AEM survey is expected to cover ~250 acres (Figure 6), and consists of flying an instrument ~100 feet above ground in straight lines spaced ~100 feet (Appendix C).

Depending on access, need, and installation costs, between four to six additional monitoring wells within MMB may be considered as part of Phase II work in MMB.

2.2.1.4.5 North of Olin (GW-413) Area

The primary target areas are the 'former Plant B production area' to investigate for possible source, and north to GW-413 and beyond to evaluate the extent of the NDMA plume (Figure 7). The seismic reflection survey work consists of 4 lines with ~5-ft geophone spacing. The seismic lines will be aimed at defining bedrock surfaces in the downgradient direction (Figure 7):

1. Oriented W-E east of the railroad tracks, ~550 ft, ~110 geophones,
2. Oriented NW-SE parallel to the railroad tracks on the western side, ~920 ft, ~184 geophones,

3. Oriented NE-SW east of the railroad tracks, ~290 ft, ~58 geophones,
4. Oriented NE-SW across the southern portion of the former cement plant property, ~700 ft, ~140 geophones,

The number and location of seismic data confirmatory borings will be determined based on the Phase I results. Eleven direct push locations to refusal (assumed bedrock) are scoped for the North of Olin area to sample deep overburden to address the NDMA plume extent data gap (Section 2.2.2) and to provide additional confirmatory information for the seismic data.

At least four monitoring well locations have been selected for Phase II to be completed in the overburden and bedrock, the latter of which will be geophysically logged (Figure 7). The screen intervals will be in the, 1) shallow overburden (S) ~10-20 ft bgs, 2) deep overburden (D) ~0-10 ft above top of bedrock, 3) bedrock (BR), where the first water-bearing fractures exist. These wells will assess potential contaminant transport to/from the bedrock.

Specifically, USEPA has suggested the potential for “*shallowly-dipping sheeting fractures*” to serve as a potential transport mechanism through the bedrock from contaminated areas to the south (Brandon 2018). Borehole geophysics will be the primary tool, along with core observations, to collect data related to the occurrence of sheeting fractures to evaluate potential mass transport through bedrock fractures. Additional monitoring well locations (1 to 3) will be installed in this area following the review of the groundwater analytical results.

2.2.1.4.6 East of Olin

The primary target areas consist of the easternmost extent of the current groundwater NDMA plume (Figure 8). The East of Olin seismic reflection survey work consists of six lines with ~5-ft geophone spacing (Figure 8):

1. Oriented N-S in the southeastern corner of the Olin property, as an extension to the existing seismic reflection line ~360 ft, ~72 geophones,
2. Oriented NW-SE parallel to the railroad tracks, ~1,120 ft, ~224 geophones,
3. Oriented SW-NE connecting line 1 to line 2, ~400 ft, ~80 geophones,
4. A) Oriented SW-NE as an extension to the west of the existing seismic reflection line, ~300 ft, ~60 geophones,

- B) Oriented SW-NE as an extension to the east of the existing seismic reflection line, ~310 ft, ~62 geophones,
- 5. A) Oriented N-S as an extension to the north of the existing seismic reflection line, ~600 ft, ~120 geophones,
 - B) Oriented N-S as a connection between the existing seismic reflection lines, ~270 ft, ~54 geophones,
 - C) Oriented N-S as an extension to the south of the existing seismic reflection line, ~670 ft, ~134 geophones,
- 6. Oriented NE-SW east of the railroad tracks across the southern edge of the NDMA plume, ~1,260 ft, ~252 geophones,

The number and location of the East of Olin Phase II confirmatory borings for the seismic data will be determined following the results of Phase I. As discussed with USEPA this effort could range from three to six wells. There are three Phase II monitoring well cluster locations currently planned to be completed in the overburden and shallow bedrock (Figure 8).

2.2.1.5 Subsequent Investigations

Olin proposes that USEPA hold final placement/location and the ultimate number of monitoring wells/borings in abeyance until the Phase I work is completed and there is consensus among the team members (USEPA and Olin) regarding this topic.

2.2.1.6 Analytic Approach

The seismic and AEM data collected for the bedrock characterization data gap will ultimately be used to inform/update the CSM and eventually the anticipated remedial design. The geophysical studies will provide the estimated depth to bedrock, and frequency and orientation of fractures for eventual input into visual modeling software to develop a 3D model (Appendix B and C). The updated CSM will provide a platform for discussions between the Olin and USEPA Team to finalize the locations for confirmatory borings and well installations to be determined in Phase II of the work plan.

2.2.1.7 Performance or Acceptance Criteria

The possible range of depth to bedrock is from ground surface to up to ~150 ft. Compounding error for estimated depths to the top of the bedrock surface using coupled

seismic information with boring data which were not verified by bedrock core samples can lead to misinterpretation of the bedrock surface (Olin 2018b).

Errors will be substantially reduced by drilling an acceptable number of confirmatory borings (~10 ft into bedrock with core samples) to validate the seismic data interpretation. The bedrock core samples are the most reliable method to identify the top of bedrock surface, so the interpretation of the bedrock surface will rely more on the confirmatory boring data than the other datasets.

The acceptable count and spacing between core samples of the bedrock surface will be established upon completion of the initial interpretation of the seismic data. As a refinement step, the seismic models will be re-run based on the bedrock confirmation data if there is a disparity greater than the expected accuracy of the seismically interpreted depths.

The accuracy of the estimated depths to the top of bedrock using the AEM data will be validated by reference to existing boring and seismic reflection/refraction data to reduce modeling error. Prior to flying the MMB area, a verification target area will be identified. This may be the CA or another location within 20 miles of the site. The verification flight will be to confirm that AEM is fit for its intended purpose and that the ensuing data collection will meet quality assurance/quality control (QA/QC) requirements. For the AirTEM® instrument, raw noise is filtered from the datasets by computing probability distribution from lowest to highest value. The noise levels should not exceed the noise limits from 10% to 90% of the data collected for any given line. The calibration of the instrument is in nT/s (unit of the change in the magnetic field, nanoteslas per second), and the accuracy of the system is ~1% within the units.

2.2.2 NDMA Plume Characterization Data Gap

NDMA in groundwater has been recognized as a Site contaminant. The USEPA has identified the elevated NDMA concentrations in GW-413D as a data gap due to the lack of understanding of the source of NDMA in this area, its migration pathway, and insufficient data constraining the NDMA plume boundaries (USEPA 2019d). In addition, the source, fate and transport characteristics for NDMA contaminated groundwater in the northern area of the Olin property require additional conceptualization.

The GW-413S/D/BR well cluster was installed in 2015 to characterize the groundwater to the north of the Olin property with the GW-413D well containing elevated NDMA concentrations in comparison to surrounding monitoring wells. The North of Olin NDMA data gap will be addressed with a subsurface investigation of soil and groundwater, and the installation of additional monitoring wells.

The DQOs for the NDMA plume characterization data gaps are described in this section, broken into subsections in accordance with USEPA guidance.

2.2.2.1 NDMA Data Gap Problem Statement

2.2.2.1.1 North of Olin (GW-413) Area

The primary issue for the NDMA plume characterization data gap is a lack of understanding of the source, migration pathway and fate of NDMA from the source to GW-413D and beyond. The USEPA and Olin have both identified that deep overburden monitoring wells in the northern portion of the Olin property have lower NDMA concentrations than GW-413D, and that the source and extent of the NDMA plume to the north of the Olin property remains unbounded. Following the GW-413S/D/BR monitoring well cluster installation in 2015, two additional well clusters (GW-415D/BR and GW-416D/BR) were installed in 2017 to investigate deep overburden and shallow bedrock to the north; however, the spacing and location of the wells raised concern over the characterization of NDMA in the North of Olin area. Further, the data from GW-413, GW-415, and GW-416 doesn't fully bound the NDMA impacts in the area. Consequently, USEPA identified the area as a data gap during review of the draft RI/FS (USEPA 2019a, c).

USEPA has also commented on the potential for mass transport along bedrock fractures which would be undetected in the overburden groundwater. This data gap is also addressed in the bedrock characterization data gap discussion Section 2.2.1, and specifically for the North of Olin in Section 2.2.1.4.5. The important Phase I elements include:

- Evaluating the former Plant B Production Area building as a potential NDMA source.
- Defining the lateral and vertical extent of the NDMA plume in the vicinity of GW-413.

- Understand the source, migration pathway and fate of NDMA from the source to, and downgradient from GW-413D.

The overall conceptual model for the Site has been described in the DQO problem statement section of the bedrock characterization data gap (Section 2.2.1.1). The conceptual model for North of Olin currently assumes the NDMA plume follows the groundwater flow directions for the area, which is generally from south to north. A groundwater divide exists in the vicinity of the Olin property, north of the CA (Figure 7), generally coincident with the surface water divide between the Ipswich and Aberjona watersheds. Based on the current understanding of the groundwater flow system, the source for NDMA detected to the north of the Olin property is either near (or north of) the groundwater divide, or is independent of the overburden groundwater flow system along bedrock fracture networks.

The data types for the NDMA plume characterization data gap work are direct push soil and groundwater samples, and monitoring well groundwater samples for Phase I. Based on the results of Phase I, Phase II will involve installing monitoring well clusters to the north of Olin, and groundwater sampling.

2.2.2.1.2 East of Olin Area

Other issues related to the NDMA characterization data gap pertain to the East of the Olin area. The USEPA and Olin have both identified that the extent of the NDMA plume to the east of the Olin property remains potentially unbounded. USEPA has also commented on the potential for mass transport along bedrock fractures which would be undetected in the overburden groundwater. This data gap is also addressed in the bedrock characterization data gap discussion in Section 2.2.1, and specifically for the East of Olin area in Section 2.2.1.4.6. The primary issue related to NDMA (to be addressed in Phase II of the DGWP) is to verify the eastern boundary of NDMA impacts near East Ditch.

The conceptual model for this area currently assumes that the NDMA plume follows the groundwater flow directions for the area, which is generally from northwest to southeast. Based on the seismic survey results of Phase I, Phase II will involve installing monitoring well clusters to the east of Olin, and groundwater sampling.

2.2.2.2 NDMA Data Gap Study Goals

The study goals for the NDMA characterization data gap are to: 1) determine if a source can be identified for the NDMA plume to the north of Olin, 2) verify the extent of NDMA contamination to the north of Olin, 3) develop a conceptual model on the source and transport of NDMA to the north of Olin, and 4) determine locations for additional monitoring well clusters.

The principal study questions for the NDMA characterization data gap work are:

- What is the source of the elevated NDMA concentrations detected in GW-413D?
- What is the lateral and vertical extent of NDMA contamination in the overburden and bedrock in the vicinity of GW-413?
- What is the direction of mass transport to the north of the GW-413 area?

Alternative outcomes that can occur on answering these questions are:

- The soil and/or groundwater sampling results for NDMA concentrations are all elevated, or
- The soil and/or groundwater sampling results for NDMA concentrations are either not detected or do not exhibit any particular pattern consistent with the current understanding of the NDMA plume extent and CSM for the fate and transport.

The decision statements for the NDMA characterization work are:

- Determine whether the former Plant B production area is a potential source of elevated NDMA concentrations to the north of Olin.
- Define the extent of NDMA in the vicinity and north of GW-413.

2.2.2.3 NDMA Data Gap Information Inputs

Sampling data from previous investigations for the Site will be incorporated with the soil and groundwater data collected as part of this work plan implementation to update the CSM and determine locations for additional monitoring well clusters. Previous investigation work related to the RI/FS for the Site will form the basis for the sampling procedures and analytical methods. The primary information required for this study is the NDMA

concentrations in soil and groundwater (where inorganics will also be analyzed), along with surveyed sampling locations and depths/sampling intervals.

2.2.2.4 NDMA Data Gap Boundaries of the Study

The Phase I NDMA characterization work includes specified locations for direct push soil and groundwater sampling at select locations/wells for the North of Olin Site area (Figure 7).

The soil sampling area will be located in the immediate vicinity of the former Plant B production area (Figure 7). There are 6 locations proposed where soil will be sampled with direct push borings to the depth of refusal. Soil will be sampled at designated depth intervals with a sampler connected the base of the drilling rod. Details for the sampling methods are described in the Field Sampling Plan (FSP) (Appendix E).

Eleven locations have been selected to sample groundwater with direct push borings to the refusal depth (Figure 7). These groundwater samples will be collected with an SPF-15 slotted screen or a slotted rod or equivalent. At the base of each boring the rods will be pulled back to allow water to enter the screen. The borings will be located by GPS and the ground surface elevation at each will be surveyed.

Existing wells in the North of Olin area will also be sampled for groundwater: GW-413, GW-415, and GW-416. These locations were discussed in the GW-413 Supplemental Investigation comments (Olin 2018a). In addition, there will be a synoptic round of groundwater level measurements for 14 wells.

These data will provide additional groundwater elevation and analytical data to inform the CSM. Details for the sampling methods are described in the FSP (Appendix E).

The soil and groundwater sampling is expected to take ~1 week. Upon collection of the soil and groundwater samples, they will be preserved and sent to an analytical laboratory.

2.2.2.5 NDMA Data Gap Analytic Approach

The NDMA results from the soil samples referenced above will be evaluated to determine whether the former Plant B production area could have been a source of the NDMA plume to the north of Olin. Concentrations for additional COCs from the target analyte list (Wood

2019a) will be evaluated to determine any additional source information and to update the CSM. The groundwater analyses will also be evaluated to locate additional monitoring well clusters as appropriate and necessary, update the NDMA plume contour drawings, and update the CSM.

2.2.3 DAPL Pool Characterization Data Gap

The primary data gaps for DAPL pool characterization are the bedrock topography and the extent of DAPL in the weathered and fractured portions of the bedrock. The elevation of the top of DAPL and diffuse groundwater will be determined by analysis of groundwater from multiport wells installed within the bedrock depressions where DAPL has collected.

Currently there are no sampling ports installed in the bedrock beneath the known DAPL pools to characterize the extent of DAPL in competent and fractured bedrock. Site data, which includes extensive areas of diffuse groundwater in bedrock adjacent to the pools, suggests DAPL transport through bedrock fractures may be occurring by gravity flow with subsequently dilution, so data are required to validate the role of DAPL within the bedrock. Other issues are directly related to the bedrock characterization work because the bedrock surface and fracture characterization will determine the overall extent of the DAPL.

The bedrock characterization data gap (Section 2.2.1) applies to all of the Site areas (CA, Jewel Drive, Main Street., MMB, North of Olin, and East of Olin); however, the DAPL pool characterization data gap applies only to those areas with DAPL pools (CA, Jewel Dr., Main St.) and where DAPL has been identified in MMB wells. The DAPL characterization data gap will be addressed concurrent with the bedrock characterization data gap work during Phase II, when bedrock borings are drilled and bedrock groundwater samples can be collected and analyzed. Analyses will include specific gravity measurements where relevant to enhance the accuracy of the DAPL definition.

Once the bedrock characterization data gap work is completed, additional DAPL characterization data gap work will follow with the installation of multiport wells in the DAPL pool areas. The data generated over the phased approach (to be provided with the Phase II and Phase II work plans) are necessary to inform the CSM, and provide a better understanding of the extent of DAPL and diffuse groundwater in the overburden and

bedrock. The results of the study will refine the basis for DAPL volume calculations, an eventual TIE and future remedy design work. The detailed DQOs for the DAPL characterization data gap will be provided with the Phase II Data Gaps Work Plan upon completion of Phase I. The Phase II DGWP will also specify casing completion methods in bedrock below the DAPL pools.

2.2.4 Site-wide Issues

Additional data gaps have also been identified as ‘site-wide’ issues, which include bedrock fracture interconnectivity, surface/groundwater interaction and the DAPL/diffuse layer groundwater specification. The bedrock fracture interconnectivity issue is addressed with the bedrock characterization data gap, which will combine all the data collected into a site-wide depiction of the bedrock surface and fractures identified by seismic reflection data and borehole logging. The surface/groundwater interaction and DAPL/diffuse definition topics are addressed below.

2.2.4.1 Surface/groundwater Interaction

The interaction and connection between surface water and groundwater was identified as a data gap in the June 26th, 2019 meeting with the USEPA. The relationship between groundwater and surface water is an element of the CSM needing further refinement, especially in areas where contaminated groundwater can potentially discharge to surface water features. Of particular interest is the area north of the GW-413 well cluster, where an unidentified ditch flows into an open water body on the northeast side of the DSM Neo Resins property off Main St. (Figure 9a and 9b). This surface water feature eventually discharges to the Maple Meadow Brook to the north.

Data from existing surface water locations in the vicinity of the Site are available from the USGS (Figure 9a and 9b). Stream gauging data was collected in the 1960’s and 1970’s in Maple Meadow Brook where Main Street crosses the channel. There is also a staff gauge in Maple Meadow Brook at the Middlesex Canal, but data has not been found for this location. Additional USGS surface water sampling sites exist upstream on the Maple Meadow Brook and Sawmill Brook, and the availability of surface water elevations at these sites is being investigated.

This work plan includes installation of surface water gauges to be coupled with adjacent groundwater level monitoring points (Figure 9). The difference between the synoptic measurements of surface water and groundwater elevations, in addition to any seasonal patterns will help determine whether groundwater is discharging to surface water and whether there is associated seasonality. These data will also help to refine the CSM.

2.2.4.2 DAPL and Diffuse Layer Groundwater Specification

The USEPA identified that the discrimination between DAPL and diffuse groundwater layers within the groundwater column would require an update of the inputs/methods used to distinguish between groundwater, diffuse groundwater, and DAPL, and an analysis as to whether the post-2001 data comports with the earlier definition. This data gap requirement will be addressed in a stand-alone technical memorandum as discussed in the revised OU3 RI (Wood 2019a).

2.3 Project Team

Olin's core project team consists of five people from environmental consulting companies Geomega (a Principal Geochemist and a Hydrogeologist) and Wood (a Senior Project Manager, a Project Manager, and a Hydrogeologist) in addition to two people from Olin (an Environmental Remediation Director and a Technical Representative/Hydrogeologist). The team will also include groups of subcontractors hired to:

1. Collect and process the seismic reflection data,
2. Conduct the AEM survey,
3. Drill confirmatory/monitoring well borings,
4. Log boreholes completed within the bedrock,
5. Operate the direct push equipment,
6. Collect soil and groundwater samples,
7. Measure groundwater levels, and
8. Install surface water gauging stations.

The core project team members from Olin, Wood, and Geomega will supervise and guide the decision making process for the data collection for the subcontractors during each Phase, and will also interact regularly with the USEPA for data interpretation and decisions on data completeness and adequacy. Wood and Geomega will house the collected data to be interpreted and used to update the 3D model and update the CSM.

3 Work Plan

The following subsections describe the Scope of Work for the Data Gaps Work Plan based on the DQOs outlined for the identified data gaps in Section 2. Phase I is the primary focus for this work plan; however, the anticipated events for Phases II and III are also discussed.

3.1 Existing data

Data collected at the Site includes bedrock surface investigations, borings through overburden into bedrock, geophysical well logging, soil investigations, and monitoring well installation and sampling programs, which collectively define the current extent of groundwater impacts and the current CSM. The existing data and investigative studies have been described for the Site in the OU3 RI in more detail by Olin (Amec 2018c; Wood 2019a). The current understanding of the CSM has also been documented thoroughly through the RI reporting process, and is described briefly for the Site in the DQO section for the bedrock characterization data gap (Section 2.2.1.1).

3.2 Scope of Work

This section summarizes the Phase I scope of work to close the data gaps identified at the Site. The Phase I work plan consists of the seismic reflection survey, AEM survey, monitoring well replacements, direct push soil and groundwater sampling, monitoring well sampling, and surface water gauging station installation.

3.2.1 Seismic reflection survey lines

The characterization of the bedrock surface and potential bedrock fractures will be addressed through the collection of seismic reflection data from the anticipated 47 seismic lines (Figures 3 through 8). The Figures provide the details on the approximate location, orientation, and lengths for each of the seismic lines, as well as the existing data, and are also individually described in the bedrock characterization DQO Section 2.2.1.4. The seismic lines are oriented to utilize existing boring information which has helped to identify the bedrock surface. While the location and orientation of the seismic lines are centered on perceived bedrock depressions and perpendicular to the inferred bedrock fracture orientations presented by USEPA, the presence of buildings, railway lines, access agreements, and/or

inaccessible areas will constrain their precise location. The actual location of the seismic lines will be contingent on access agreements and the location of existing buildings, structures, and environmental hazards.

The Phase I seismic reflection survey for the anticipated 47 seismic lines is separated by Site area and is expected to occur based on the order presented in Section 2.2.1.4. The processing and interpretation of the data to estimate the depth to bedrock and fractures/structures will occur subsequent to the field survey. Existing knowledge on depth to bedrock and seismic properties of the subsurface materials will be provided to the drillers and relevant subcontractors to enhance the interpretation of the data and minimize the estimation error. Upon interpretation of the seismic data, the bedrock surface topography will be updated, and any conflicting information will be addressed. Once the bedrock topographic surface is finalized, locations for confirmatory borings will be determined for Phase II.

The technical approach and additional details for the seismic survey work plan are included as Appendix B.

3.2.2 AEM Survey

Phase I work will consist of an AEM survey of the undeveloped areas in the MMB area (Figure 6). The work will involve flying a helicopter with an instrument suspended from the base. Relevant entities (e.g., the town of Wilmington, the local police department, and residents abutting the MMB flight area) will be notified of the survey.

The instrument transmits and receives EM data to be processed and modeled, with the flight paths determined by GPS measurements. Once the data is collected, processing and modeling of the data will occur in an office setting using widely recognized computer programs. The estimated depth to bedrock, and if possible, fractures, and DAPL, etc. will be generated using 3D grid (voxel) files that will be used to update the CSM.

The technical approach and details for the AEM survey work plan are included as Appendix C.

3.2.3 Monitoring Well Replacement

Phase I includes replacing monitoring well GW-26 (Figure 4), a single well completed in the overburden that was recently destroyed. The location of the former well is in the Jewel Drive area, and is currently inaccessible; therefore, the well will be relocated ~50 ft to the west, adjacent to the north side of the building (Figure 4). The replacement GW-26 monitoring well will be installed as a cluster as described in Section 2.2.1.4.2.

The overburden boring will be advanced to bedrock using drilling methods consistent with the RI/FS Work Plan (MACTEC 2009a, b; Appendix D). Depending on the thickness of saturated overburden, either a shallow well or a paired shallow and deep paired well will be installed. Once the overburden well is installed, an adjacent borehole will be advanced into bedrock, and a shallow bedrock well installed that is screened across the first water bearing fracture zone encountered. A deep (~100 ft below bedrock surface) borehole will then be advanced and logged for the installation of a deep bedrock well. It is anticipated that the installation will require closely sequenced borehole completion and borehole geophysical logging, and recommendations provided as a field technical memorandum (in real time) to the USEPA for concurrence on well screen placement. All aspects of drilling, investigative derived waste (IDW) management, well construction, development and sampling will be conducted consistent with the RI/FS Work Plan, Addendum IV (MACTEC 2009a, b; Appendix D).

3.2.4 Direct Push Soil Sampling

Phase I includes six locations at the former Plant B production area for soil sampling to depth of refusal (Figure 7). The goal is to investigate the potential source of the NDMA plume to the north of Olin, particularly in relation to the elevated concentrations detected in GW-413D. The sampling methods, depth intervals, and details for the work are described in the FSP (Appendix E).

3.2.5 Direct Push Groundwater Sampling

Phase I includes 11 locations in the vicinity of GW-413 (Figure 7). The direct push investigation will characterize the lateral extent of groundwater contamination and material characteristics in the overburden to depth of refusal. The proposed locations address areas

upgradient and downgradient (including the area to the west) from GW-413. The sampling methods, depth intervals, and details for the work are described in the FSP (Appendix E).

3.2.6 Groundwater Sampling from Existing Monitoring Wells

GW-413S/D/BR, GW-415D/BR and GW-416D/BR (Figure 7) will be sampled during Phase I to supplement the groundwater data: The samples will be analyzed for NDMA, ammonia, chloride, magnesium, sodium, sulfate, with field measurements for specific conductivity and pH. Additional details for the sampling methods are described in the FSP (Appendix E).

In addition, a synoptic round of groundwater level measurements will be collected from a subset of Site wells (Appendix E).

3.2.7 Surface Water Gauging Station Installations

Phase I includes the installation of nine new staff gauges and one new piezometer across the Site to monitor surface water levels (Figure 9). USGS style staff gauges will be installed using a hand-driven stainless steel rod. The elevation of the top of the gauge will be surveyed so both stage and water elevation can be computed. In the GW-413 area, a hand driven piezometer will be substituted for a staff gauge west of Morse Avenue to allow direct measurement of stream water depth, elevation and underlying groundwater depth and elevation. The piezometer location will also be surveyed. Details for the staff gauge and piezometer installations are described in the FSP (Appendix E).

3.3 Phase II Work Plan

The scope of Phase II will be determined based on the results of the Phase I seismic and AEM surveys, soil and groundwater sampling results, relevant historical data and in conjunction with USEPA meeting(s). It is expected to include drilling confirmatory/monitoring well borings for core sampling, and detailed logging (e.g., lithology, caliper, acoustic, SP, R, Temperature, and Conductivity, OTV/ATV, HPFM) of the bedrock for select locations where monitoring well clusters will be installed. Drill-stem straddle packer sampling/testing of water-bearing fractures and competent bedrock will assess the hydraulic properties and water quality of the bedrock formations. Analytical sampling concurrent with the boring program will further characterize the DAPL and diffuse

groundwater within the bedrock and any water-bearing fractures. Groundwater samples will also be analyzed for specific gravity measurements where relevant.

Monitoring well clusters (in overburden and bedrock) will be installed at selected locations, including the GW-59 and MP-4 replacements. A range of boreholes /wells numbers has been indicated in earlier discussions and the final number will be based on consensus discussions between the USEPA and Olin. The anticipated range of Phase II borings for each Site area is described in Section 2.2.1.4 above, and summarized here:

- CA: 5-10 confirmatory boring locations, where at least 4 will be selected for monitoring well clusters. Multiport wells will be considered based on the Phase I data review (Figure 3).
- Jewel Dr.: At least 5 confirmatory borings locations, where at least 2 will be selected for monitoring well installation, with additional 1 to 2 multiport wells (Figure 4).
- Main St.: 15-20 confirmatory boring locations, where at least 12 will be selected for monitoring well clusters. Multiport wells will be considered based on the Phase I data (Figure 5).
- MMB: Depending on access, need, and installation costs, 4-6 monitoring well locations may be considered (Figure 6).
- North of Olin: At least 4 monitoring well clusters will be installed with the number and locations of confirmatory borings will be determined following evaluation of the Phase I seismic data (Figure 7).
- East of Olin: At least 3 monitoring well clusters will be installed with the number and locations of confirmatory borings to be determined following evaluation of the Phase I seismic data (Figure 8).

Additional seismic reflection lines may be included in Phase II, depending on the seismic survey results from Phase I. The details and methods for the Phase II work will be updated in the Phase II DGWP after consultation with the USEPA.

3.4 Phase III Work Plan

The scope of Phase III work plan will be determined based on the Phase I and Phase II results together with relevant historical data. It may consist of drilling additional confirmatory/monitoring well borings/installations, if needed/relevant. The details and

methods for the Phase III work will be updated in the Phase III DGWP after consultation with the USEPA.

4 Work Plan Schedule

The anticipated schedule and timing for this DGWP is specified for Phase I, which is anticipated to begin as early as Q4 2019. Following the data collection, analysis, interpretation, reporting, and meetings, Phase II is anticipated to begin by Q3 2020. The Phase III schedule will be contingent on the completion and results of Phase I and II.

4.1 Phase I Schedule Components

Phase I work consists of seismic surveys, an AEM survey, soil and groundwater sampling, and monitoring well drilling/logging/construction/sampling. Some of the work is expected to occur concurrently (e.g., soil sampling and seismic work); however, the implementation of the work will depend on USEPA concurrence/approval, access agreements with the exception of CA, availability of appropriate subcontractors, and the weather.

4.1.1 USEPA Concurrence

None of the work associated with this DGWP will begin until consent/approval by the USEPA. Communication between Olin and USEPA to address data gap topics is ongoing. To frame the project schedule, Olin assumes that USEPA will provide concurrence/approval of the DGWP by early October 2019.

4.1.2 Access agreements

Following the USEPA consent to the tasks outlined in this DGWP, access will be sought for all the Site areas outside of Olin property. However, Olin will initiate the access agreement process (e.g., preparing relevant draft agreements) while awaiting the approval of this DGWP. The CA and onsite North of Olin soil sampling work will start immediately following USEPA consent, based on subcontractor availability and weather.

The process for access agreements for residential, commercial, and industrial properties as well as the public right-of-ways involves contacting property owners and the Town, and informing them of the work that is required to be completed on their properties, and obtaining written agreement for the work to proceed (Appendix H). Olin anticipates

scheduling a meeting with the Town to discuss access, the AEM survey and other details outlined in the DGWP that are relevant to the town.

4.1.3 Seismic Reflection Survey

As no access agreements are needed for the CA, we estimate the seismic reflection survey for the CA will be completed within 2-3 weeks. This schedule however, is contingent upon subcontractor availability and the weather.

After access agreements have been received for the remaining Site areas, the schedule is expected to be:

- Jewel Dr. seismic data to be collected in ~1-2 weeks;
- Main St. seismic data to be collected in ~3-4 weeks;
- North of Olin seismic data to be collected in ~1 week;
- East of Olin seismic data to be collected in ~2 weeks.

Following data collection, the data processing, modeling, and reporting is expected to take ~4-6 weeks. A draft report will be prepared by the seismic survey subcontractors and submitted to Olin's core project team for review. A condensed form of the survey results will be included in the Phase II DGWP, and the estimated depth to bedrock data will be incorporated into a 3D bedrock model and used to update the CSM. The total timing to receive the seismic survey results for all of the Site areas is expected to be ~3 months from the start of work contingent on weather conditions.

4.1.4 AEM survey

The AEM survey is anticipated to be concurrent with the seismic survey data collection. Assuming that contractors are available to begin work shortly after agreements are met and the town has been informed of the program, mobilization and site preparation will take ~1 week. The collection of the EM data is expected to take ~2-3 days, and processing, modeling, and reporting of the data is expected to take ~5-6 weeks. A condensed report of the survey results will be included in the Phase II DGWP, and the estimated depth to bedrock data will

be incorporated into a 3D bedrock model that will be used to update the CSM. The total timing to receive the AEM survey results is expected to be ~2 months.

4.1.5 North of Olin: Former Plant B Production Area Soil Sampling

Mobilization, site preparation, and soil sampling is expected to take ~3 weeks. The samples will be sent to the analytical laboratory with results expected in ~3 weeks. Based on this schedule, the direct push sampling results should be received within ~2 months from the start of work.

4.1.6 North of Olin: GW-413 Area Groundwater Sampling and Measurements

Mobilization, site preparation, and the direct push groundwater sample collection are expected to take ~1-2 days per bore location. The samples will be sent to the analytical laboratory with results expected in ~3 weeks. Based on this schedule, the direct push groundwater sampling results should be received within ~2-3 months from the start of work.

Concurrent sampling of the GW-413/415/416 well clusters will take ~2 days. The samples will be sent to the analytical laboratory with results expected in ~3 weeks.

Water levels will be measured within 1 day at the wells listed in the FSP (Appendix E).

4.1.7 Monitoring Well Replacement

The Phase I work plan schedule for the replacement of GW-26 is expected to take ~2 months; the anticipated activities include, mobilization to the site, site preparation, drilling and lithologic logging of the borehole to bedrock. The schedule for the detailed borehole logging, construction, and development is described in the following sections.

4.1.7.1 Monitoring well logging/testing

Following the completion of bedrock drilling to ~100 ft below the top of bedrock, the open borehole in the bedrock will be logged for caliper, acoustic, SP, R, Temperature, and Conductivity, OTV/ATV, and HPFM, which is expected to take ~1 day per borehole. All information on potential water-bearing fractures within the bedrock will be compiled.

4.1.7.2 Well construction and development

Once the borehole has been logged and sampled, the specifications for the bedrock well(s) will be determined and the wells constructed and developed. Construction and development of the GW-26 monitoring well cluster is expected to take ~2 weeks.

The schedule for the drilling and construction of the GW-26 replacement is expected to require ~2 months from the start of work.

4.1.8 Surface water gauging station installations

The schedule for the installation and surveying of the surface water gauging stations will be concurrent with the other Phase I tasks. Up to two staff members from Wood will access the locations and install the gauges/piezometers as described previously. The anticipated schedule for the installations is ~1-2 days. Following the installations, the top of the gauges will be surveyed, which is anticipated to take ~2-3 days.

4.1.9 CSM update and USEPA meeting

Once all of the data for Phase I has been received, the 3D bedrock model will be updated. This involves the input and interpolation of depth to bedrock, and bedrock fractures. These data, combined with the new soil and groundwater information will aid in the development of a new CSM, which is expected to take up to a month. Once the CSM is updated, a meeting will be held with the USEPA to discuss this model and the proposed work plan for Phase II. This will primarily involve the selection of confirmatory boring/monitoring well locations, but may also include additional seismic survey lines. A Phase II DGWP document will then be prepared that describes the Phase II DQOs and scope of work. The overall timing for the updates to the CSM, USEPA discussions, and completion of the Phase II DGWP is expected to be ~3 months after the Phase I work is completed.

4.2 Phase I Schedule Summary

Assuming the DGWP is accepted by the USEPA with minimal edits, and the access agreements and subcontractor availability are not delayed, Phase I can start as early as Q4 2019. This schedule is contingent upon USEPA approval, access agreements, subcontractor availability, and weather. An estimated DGWP schedule is summarized in a Gantt chart

(Figure 10). Assuming the work can be completed concurrently for each of the Site areas, and considering accessibility and weather issues during the winter, the Phase I work is anticipated to be completed, results received and interpreted by the end of Q2 2020. Once the CSM is updated and the Phase II DGWP is agreed to by the USEPA, Phase II is anticipated to begin in Q3 2020.

4.3 Phase II and III

A similar schedule to the Phase I work is expected for Phase II contingent on the USEPA consent, access agreements, and data collection/site preparation/mobilization. The specific tasks for the work plan will depend on the results of Phase I, but may initially involve additional seismic surveys, and follow-up drilling and logging the confirmatory borings/monitoring wells. Once the monitoring wells are constructed and developed, groundwater samples will be collected and analyzed. The results of the borings and sampling data will aid in developing an updated CSM that will be reported to the USEPA for review and discussion. The work plan for Phase III will then be developed in conjunction with the USEPA.

5 Quality Control

Several documents are referenced and attached to accompany the DGWP to ensure these data are collected to meet the DQOs, and that the work plan structure is consistent with the description in Section II.F.2B of the Statement of Work (SOW), Remedial Investigation and Feasibility Study, Olin Chemical Superfund Site, prepared by the USEPA Region I – New England (USEPA 2007). The Field Sampling Plan (FSP) describes the sampling program for the Phase I soil and groundwater investigation at the North of Olin Site area (Appendix E). Standard Operating Procedures (SOPs) for the field work items are referenced in the FSP and DGWP (Appendix F).

The quality control documents accompanying this work plan were developed during the RI/FS Work Plan (MACTEC 2009a), and consist of the Quality Assurance Project Plan (QAPP), Site Management Plan (SMP), Community Relations Support Plan (CRSP), and the Health and Safety Plan (HASP):

- The QAPP provides QA/QC requirements to ensure that the data obtained is suitable for its intended purpose (Appendix G).
- The SMP provides detailed procedures for site access, site security, traffic and noise control, and management of waste to be used during implementation of the fieldwork (Appendix H).
- The CRSP provides a written understanding and commitment of how Olin will support the USEPA's Community Relations Program at the Site (Appendix H).
- The HASP provides health and safety-related procedures to be followed during implementation of all field activities (Appendix H).

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Tables

Table 1. Summary table of Data Gaps Work Plan.

Area	Phase I	Phase II
Containment Area	9 seismic reflection lines	4-10 borings (10 ft into bedrock) 2-4 monitoring well clusters (into top 100 ft of bedrock) Borehole geophysical logging 2 multilevel piezometers
Jewel Drive	6 seismic reflection lines Replace GW-26 with monitoring well cluster Borehole geophysical logging	5-8 borings (10 ft into bedrock) 1-2 multilevel piezometers
Main Street	21 seismic reflection lines	15-20 borings (10 ft into bedrock) 12+ monitoring well clusters (into top 100 ft of bedrock) Borehole geophysical logging 2+ multilevel piezometers (replacing MP-4 and GW-59)
Maple Meadow Brook	AEM survey	4-6 monitoring well clusters (depending on access)
North of Olin	6 seismic reflection lines 6 geoprobe soil sampling locations (to bedrock) 11 geoprobe groundwater sampling locations (to bedrock) Monitoring well groundwater levels and analytical sampling	Confirmatory borings to be determined following Phase I 4-7 monitoring well clusters (into top 100 ft of bedrock) Borehole geophysical logging
East of Olin	7 seismic reflection lines	3-6 confirmatory borings 3 monitoring well clusters (into top 100 ft of bedrock) Borehole geophysical logging

Table 2. Compendium of Identified Data Gaps and Associated Work Plan.

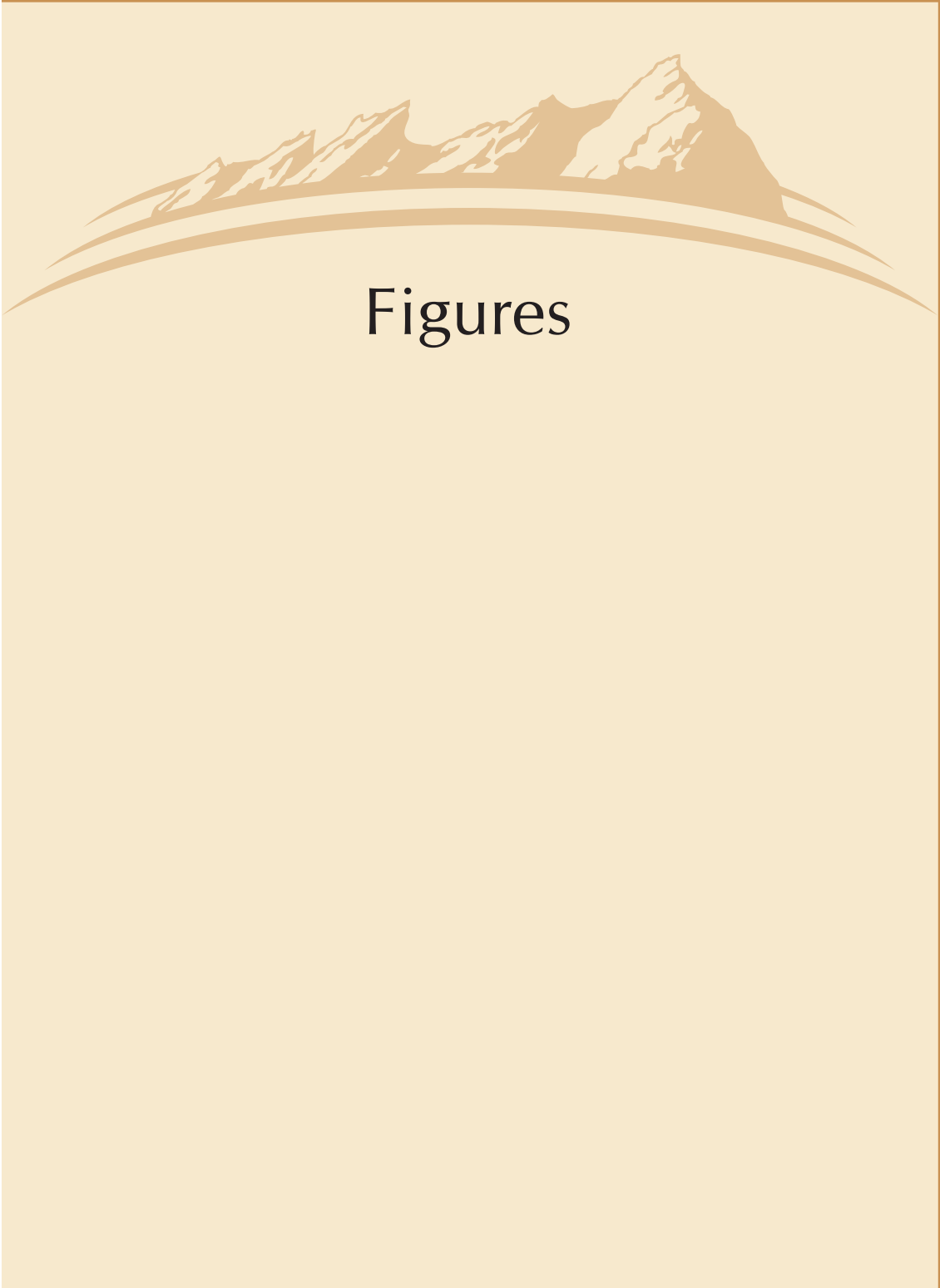
Data Gap Topic	Area(s)	Response Item	USEPA Perceived Data Gap	Phase	Simplified DQOs	Associated Work Plan
Bedrock Characterization	Containment Area	1	Seismic reflection data targeting bedrock surface depressions <u>Bedrock fracture data</u> : presence, frequency, orientation, water-bearing, cementation	I	1. Perceived problems: Center of Containment Area believed to have a depression associated with a fold axis, which may align with orientation of major faults acting as conduits and/or barriers to flow beneath the slurry wall. Multiple depressions in bedrock surface need investigation. 2. Goals: define the TOR surface in areas without data, and validate TOR surface in area with data. Identify depressions and/or evidence of faults. 3. Information Inputs: Seismic reflection data coupled with existing data/confirmatory borings and current interpretation of TOR surface, fracture orientation/frequency and water-bearing potential of fractures. 4. Boundaries of Study: Figure 3 5. Analytic Approach: Survey lines oriented perpendicular to expected fault orientations and intersections centered on bedrock depressions. Information will be used to refine the CSM. Also to guide confirmatory boring placement, and locations for monitoring well installations.	1. Nine seismic reflection survey lines to map bedrock surface and fracture frequency and orientations. 2. Interpret/model data and determine locations for confirmatory borings and monitoring wells. 3. Additional seismic lines if necessary
		2	Confirmatory borings/data for bedrock characterization <u>Bedrock fractures</u> : presence, frequency, orientation, water-bearing, cementation, hydraulic conductivity, flow direction and magnitude, groundwater quality/DAPL presence, connection to overburden Borehole logging - caliper, acoustic, SP, R, Temp, and Cond., OTV/ATV, HPFM Drill stem packer straddle pressure testing - selected locations TBD MW installation (nested and/or multi-port)	II	1. Perceived problems: Proposed seismic data requires boring data validation. Alternative interpretations suggest potential for DAPL and/or contaminant transport via fractures. Characterization of the bedrock integrity is limited. Fracture interconnectivity unknown. 2. Goals: Validate the proposed seismic reflection data. Define the TOR surface in areas without data and/or areas with significant distances between borings. Define the thickness of the weathered bedrock. Obtain core samples of bedrock to confirm bedrock depth. Identify bedrock fractures and if water-bearing, potential for groundwater flow/contaminant transport. Expand groundwater monitoring network. Determine optimal locations for additional monitoring wells. 3. Information Inputs: Depth to top of bedrock surface and top of weathered bedrock surface (if any). Detailed bore log description of overburden and bedrock materials. Lithologic logging of core samples. 4. Boundaries of Study: Figure 3 5. Analytic Approach: locations for borings to be determined following collection/interpretation/analysis of seismic survey data. Information will be used to refine the CSM and guide additional monitoring well installation, and/or extraction well installation	1. Drill appropriate number (TBD in Phase II DGWP) of confirmatory borings through overburden into competent bedrock to verify seismic data. 2. Drill and install 4 to 10 borings/wells into bedrock to be determined based on seismic survey and confirmatory borings results. 3. Conduct detailed logging (caliper, acoustic, SP, R, Temp, and Cond., OTV/ATV, HPFM) of borehole and collect core samples. 4. Conduct drill stem packer straddle testing on water-bearing fractures and competent bedrock. 5. Create a 3-D map of bedrock surface and fracture systems to assess interconnectivity between bedrock wells/fractures. 6. Determine locations for multi-port monitoring well(s) and additional nested MWs.
		3	MW installation (nested and/or multi-port) Groundwater level measurements	III	1. Perceived problems: Vertical gradients within the containment area not measured. Potential for fractures to transmit and/or contain DAPL/diffuse groundwater. 2. Goals: Measure groundwater levels. Update Conceptual Site Model. 3. Information Inputs: Depth to top of bedrock surface and top of weathered bedrock surface (if any). Detailed bore log description of overburden and bedrock materials. Lithologic logging of core samples. Measure groundwater levels and flow rates. 4. Boundaries of Study: Figure 3 5. Analytic Approach: information will be used to refine the CSM and for the design for remedial actions.	1. Install at least 1 multi-port well. 2. Additional installations will be considered in the event that there are multiple depressions in the bedrock surface.
	Jewel Drive	4	Seismic reflection data targeting bedrock surface depressions <u>Bedrock fracture data</u> : presence, frequency, orientation, water-bearing, cementation	I	1. Perceived problems: Center of bedrock depression needs additional verification, which may align with orientation of major faults acting as conduits and/or barriers to flow. Multiple depressions on bedrock surface needs investigation. 2. Goals: define the TOR surface in areas without data, and validate TOR surface in area with data. Identify depressions and/or evidence of faults. 3. Information Inputs: Seismic reflection data coupled with existing data/confirmatory borings and current interpretation of TOR surface, fault orientation/frequency and water-bearing potential. 4. Boundaries of Study: Figure 4 5. Analytic Approach: Survey lines oriented perpendicular to expected fault orientations and intersections centered on bedrock depressions. Information will be used to refine the CSM. Also to guide confirmatory boring placement, and locations for monitoring well installations.	1. Six seismic reflection survey lines to map bedrock surface and fracture frequency and orientations. 2. Interpret/model data and determine locations for confirmatory borings and monitoring wells. 3. Replace GW-26 location with a nested monitoring well into bedrock/weathered bedrock/overburden. Additional monitoring wells to be determined based on seismic survey and confirmatory boring results. 4. Additional seismic lines if necessary
		5	Confirmatory borings/data for bedrock characterization <u>Bedrock fractures</u> : presence, frequency, orientation, water-bearing, cementation, hydraulic conductivity, flow direction and magnitude, groundwater quality/DAPL presence, connection to overburden Borehole logging - caliper, acoustic, SP, R, Temp, and Cond., OTV/ATV, HPFM Drill stem packer straddle pressure testing - selected locations TBD MW installation (nested and/or multi-port)	II	1. Perceived problems: GW-26 requires replacement.Proposed seismic data requires boring data validation. Alternative interpretations suggest potential for DAPL and/or contaminant transport via fractures. Characterization of the bedrock integrity is limited. Fracture interconnectivity unknown. 2. Goals: Validate the proposed seismic reflection data. Define the TOR surface in areas without data and/or areas with significant distances between borings. Define the thickness of the weathered bedrock. Obtain core samples of bedrock. Identify bedrock fractures and if water-bearing, potential for groundwater flow/contaminant transport. Expand groundwater monitoring network. Determine optimal locations for additional monitoring wells. 3. Information Inputs: Depth to top of bedrock surface and top of weathered bedrock surface (if any). Detailed bore log description of overburden and bedrock materials. Lithologic logging of core samples. 4. Boundaries of Study: Figure 4 5. Analytic Approach: locations for borings to be determined following collection/interpretation/analysis of seismic survey data. Information will be used to refine the CSM. Also to guide additional monitoring well installation.	1. Drill appropriate number (TBD in Phase II DGWP) of confirmatory borings through overburden into competent bedrock to verify seismic data. Assess drilling to bedrock from within the building. Directional drilling of at least two confirmatory borings. 2. Conduct detailed logging (caliper, acoustic, SP, R, Temp, and Cond., OTV/ATV, HPFM) of borehole and collect core samples. 3. Conduct drill stem packer straddle testing on water-bearing fractures and competent bedrock. 4. Create a 3-D map of bedrock surface and fracture systems to assess interconnectivity between bedrock wells/fractures. 5. Determine locations for multi-port monitoring well(s) and/or nested MWs.
		6	MW installation (nested and/or multi-port) Groundwater level measurements	III	1. Perceived problems: DAPL/diffuse groundwater extent within bedrock uncertain. Potential for fractures to transmit and/or contain DAPL/diffuse groundwater. 2. Goals: Measure groundwater levels. Obtain GW samples. Update Conceptual Site Model. 3. Information Inputs: groundwater levels and flow rates. 4. Boundaries of Study: Figure 4 5. Analytic Approach: information will be used to refine the CSM and for the design for remedial actions	1. Install at least two multi-port wells to evaluate DAPL drawdown and fractured bedrock remediation. 2. Additional installations will be considered in the event that there are multiple depressions in the bedrock surface.

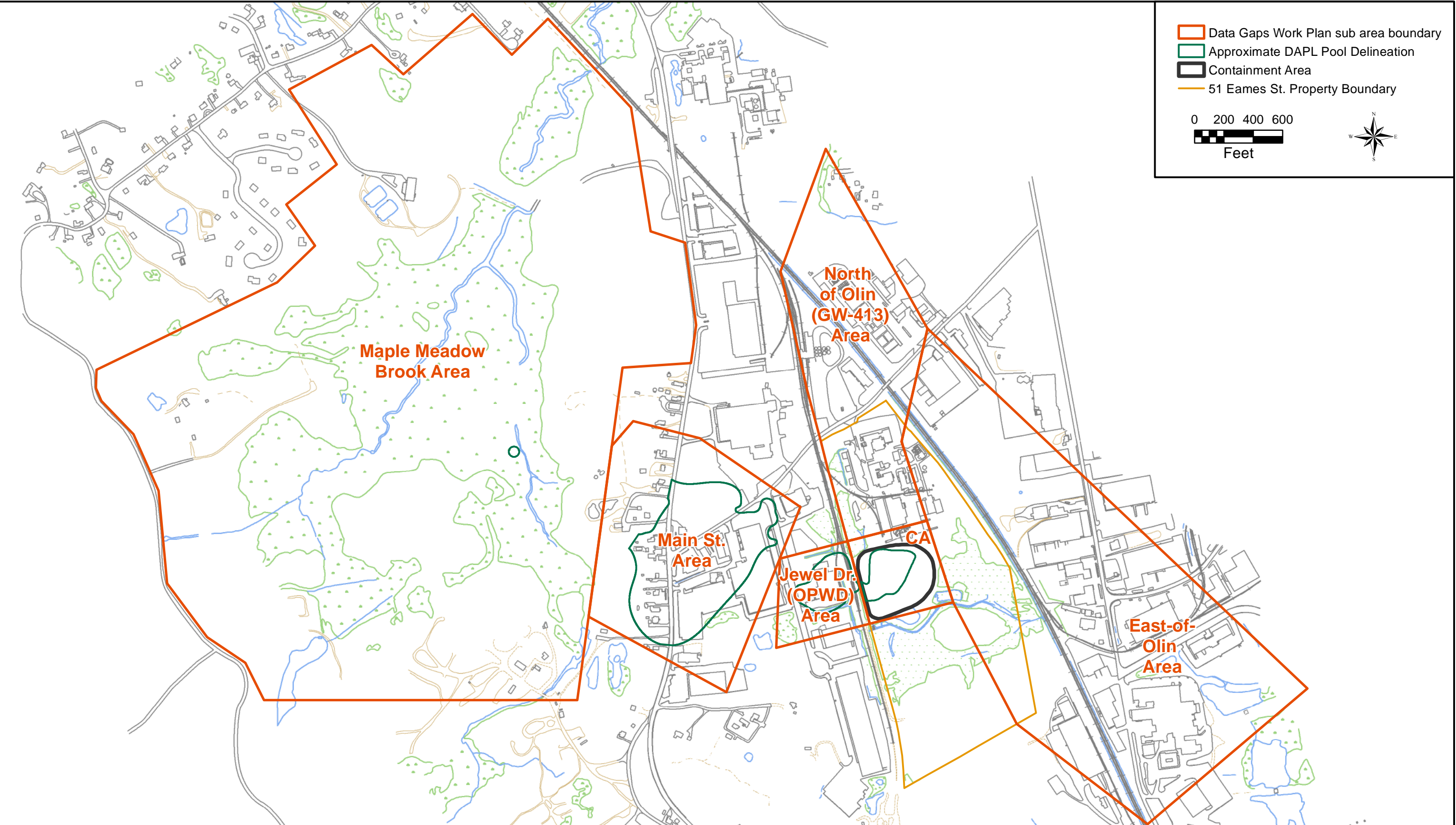
Table 2. Compendium of Identified Data Gaps and Associated Work Plan.

Data Gap Topic	Area(s)	Response Item	USEPA Perceived Data Gap	Phase	Simplified DQOs	Associated Work Plan
Bedrock Characterization	Main Street	7	Seismic reflection data targeting bedrock surface depressions <u>Bedrock fractures</u> : presence, frequency, orientation, water-bearing, cementation	I	1. Perceived problems: Western portion of TOR surface, areas without data and/or data that isn't properly validated by boring data. Alternative interpretations suggest potential for DAPL transport over TOR surface depressions and/or via bedrock fractures/faults previously uncharacterized. 2. Goals: define the TOR surface in areas without data, and validate TOR surface in area with data. Identify depressions and/or evidence of faults. 3. Information Inputs: Seismic reflection data coupled with confirmatory borings and current interpretation of TOR surface, fault orientation/frequency and water-bearing potential. 4. Boundaries of Study: Figure 5 5. Analytic Approach: Survey lines oriented perpendicular to expected fault orientations and intersections centered on bedrock depressions and highs. Information will be used to refine the CSM and for the design for remedial actions. Also to guide confirmatory boring placement, and monitoring and extraction well placement	1. Twenty-one seismic reflection survey lines to map bedrock surface and fracture frequency and orientations. 2. Interpret/model data and determine locations for confirmatory borings and monitoring wells. 3. Replace GW-59 location with a nested monitoring well into bedrock/weathered bedrock/overburden. Additional monitoring wells to be determined based on seismic survey and confirmatory borings results. Replace MP-4 multiport well. 3. Additional seismic lines if necessary
		8	Confirmatory borings <u>Bedrock fractures</u> : presence, frequency, orientation, water-bearing, cementation, hydraulic conductivity, flow direction and magnitude, groundwater quality/DAPL presence, connection to overburden Borehole logging - caliper, acoustic, SP, R, Temp, and Cond., OTV/ATV, HPFM Drill stem packer testing - selected locations TBD MW installation (nested and/or multi-port)	II	1. Perceived problems: Existing and proposed seismic data requires boring data validation. Significant distances between existing boring well network. Alternative interpretations suggest potential for DAPL transport over TOR surface depressions and/or via bedrock fractures/faults previously uncharacterized. Bedrock bulk matrix vs. fractured lacks characterization. Fracture interconnectivity unknown. 2. Goals: Validate the existing and proposed seismic reflection data. Define the TOR surface in areas without data and/or areas with significant distances between borings. Define the thickness of the weathered bedrock. Obtain core samples of bedrock. Identify fractures within the bedrock and determine if water-bearing. 3. Information Inputs: Depth to top of bedrock surface and top of weathered bedrock surface (if any). Detailed bore log description of overburden and bedrock materials. Lithologic logging of core samples and detailed description of any fractures. 4. Boundaries of Study: Figure 5 5. Analytic Approach: locations for borings to be determined following collection/analysis of seismic survey data. Information will be used to refine the CSM and for the design for remedial actions and guide monitoring well placement.	1. Drill 15-20 (TBD in Phase II DGWP) of confirmatory borings through overburden into competent bedrock to verify seismic data. 2. Install at least 12 monitoring wells into bedrock te be determined based on seismic survey and confirmatory borings results. 3. Conduct detailed logging (caliper, acoustic, SP, R, Temp, and Cond., OTV/ATV, HPFM) of borehole and collect core samples. 4. Conduct drill stem packer straddle testing on water-bearing fractures and competent bedrock. 5. Create a 3-D map of bedrock surface and fracture systems to assess interconnectivity between bedrock wells/fractures. 6. Determine locations for multi-port monitoring well(s) and/or nested MW
		9	Additional MW installation (nested and/or multi-port) required Groundwater level measurements Pumping/pressure/hydraulic testing - selected locations TBD	III	1. Perceived problems: DAPL/diffuse groundwater extent within bedrock uncertain. Potential for fractures to transmit and/or contain DAPL/diffuse groundwater. Baseline configuration of DAPL pools required to assess potential for remedial actions. GW-26 decomissioned and needs replacement well. 2. Goals: Measure groundwater levels and conduct pumping tests. 3. Information Inputs: groundwater levels and flow rates. 4. Boundaries of Study: Figure 5 5. Analytic Approach: information will be used to refine the CSM and for the design for remedial actions.	1. Install 2 to 4 additional multi-port wells. 2. Additional installations will be considered in the event that there are multiple depressions in the bedrock surface.
	Maple Meadow Brook	10	Characterization of bedrock surface and fracture orientation insufficient	I	1. Perceived problem: Areas without seismic data and/or borehole data to validate the TOR surface. Determination of additional DAPL pools needed. 2. Goals: define the TOR surface in areas without data, and validate TOR surface in area with data. Identify depressions and/or evidence of faults. Identify additional DAPL pools previously uncharacterized. 3. Information Inputs: AEM survey data coupled with confirmatory borings and current interpretation of TOR surface, fault orientation/frequency and water-bearing potential. 4. Boundaries of Study: Figure 6 5. Analytic Approach: information will be used to refine the CSM and guide monitoring well placement.	1. AEM Survey in undeveloped areas 2. Bedrock surface and fracture orientation mapping (3-D). 3. Determine locations for monitoring wells.
	North of Olin (GW-413 area)	11	Characterization of bedrock surface and fracture orientation insufficient <u>Bedrock fractures</u> : presence of near horizontal "sheeting" fractures acting as conduits to flow and transport across divides	I	1. Perceived problem: Areas without seismic data and/or borehole data to validate the TOR surface. Potential for fractures (specifically "shallowly-dipping sheeting") to transmit and/or contain DAPL/diffuse groundwater. 2. Goals: define the TOR surface in areas without data, and validate TOR surface in area with data. Identify depressions and/or evidence of faults. Define the thickness of the weathered bedrock. Obtain core samples of bedrock. Identify any fractures within the bedrock and determine if water-bearing. 3. Info Inputs: Depth to top of bedrock surface and top of weathered bedrock surface (if any). Detailed bore log description of overburden and bedrock materials. Lithologic logging of core samples and detailed description of any fractures. 4. Boundaries of Study: Figure 6 5. Analytic Approach: information will be used to refine the CSM and for the design for remedial actions. Also to guide monitoring well placement.	1. Four seismic reflection survey lines to map bedrock surface and fracture frequency and orientations. 2. Interpret/model data and determine locations for confirmatory borings and monitoring wells. 3. Additional seismic lines if necessary 4. Geoprobe borings to characterize groundwater.
		12	Confirmatory borings/data for bedrock characterization <u>Bedrock fractures</u> : presence, frequency, orientation, water-bearing, cementation, hydraulic conductivity, flow direction and magnitude, groundwater quality/DAPL presence, connection to overburden Borehole logging - caliper, acoustic, SP, R, Temp, and Cond., OTV/ATV, HPFM Drill stem packer straddle pressure testing - selected locations TBD <u>MW installation</u> Bedrock characterization	II	1. Perceived problems: Alternative interpretations suggest potential for contaminated groundwater via bedrock fractures/faults previously uncharacterized. Bedrock bulk matrix vs. fractured lacks characterization. Fracture interconnectivity unknown. 2. Goals: Define the TOR surface in areas without data and/or areas with significant distances between borings. Define the thickness of the weathered bedrock. Obtain core samples of bedrock. Identify any fractures within the bedrock and determine if water-bearing. 3. Information Inputs: Depth to top of bedrock surface and top of weathered bedrock surface (if any). Detailed bore log description of overburden and bedrock materials. Lithologic logging of core samples and detailed description of any fractures. 4. Boundaries of Study: Figure 6 5. Analytic Approach: locations for borings to be determined following collection/analysis of seismic survey data. Information will be used to refine the CSM and for the design for remedial actions. Also to guide monitoring well placement	1. Drill appropriate number (TBD in Phase II DGWP) of confirmatory borings through overburden into competent bedrock to verify seismic data. 2. Drill and install 3-4 nested monitoring wells into bedrock to be determined based on seismic survey and confirmatory borings results. 3. Conduct detailed logging (caliper, acoustic, SP, R, Temp, and Cond., OTV/ATV, HPFM) of borehole and collect core samples. 4. Conduct drill stem packer straddle testing on water-bearing fractures and competent bedrock. 5. Create a 3-D map of bedrock surface and fracture systems to assess interconnectivity between bedrock wells/fractures.
	East of Containment Area	13		I	1. Perceived problem: Areas without seismic data and/or borehole data to validate the TOR surface. 2. Goals: define the TOR surface in areas without data, and validate TOR surface in area with data. Identify depressions and/or evidence of faults. 3. Information Inputs: Seismic data coupled with confirmatory borings and current interpretation of TOR surface, fault orientation/frequency and water-bearing potential. 4. Boundaries of Study: Figure 8 5. Analytic Approach: information will be used to refine the CSM, sources fate and transport.	1. Six seismic reflection survey lines.

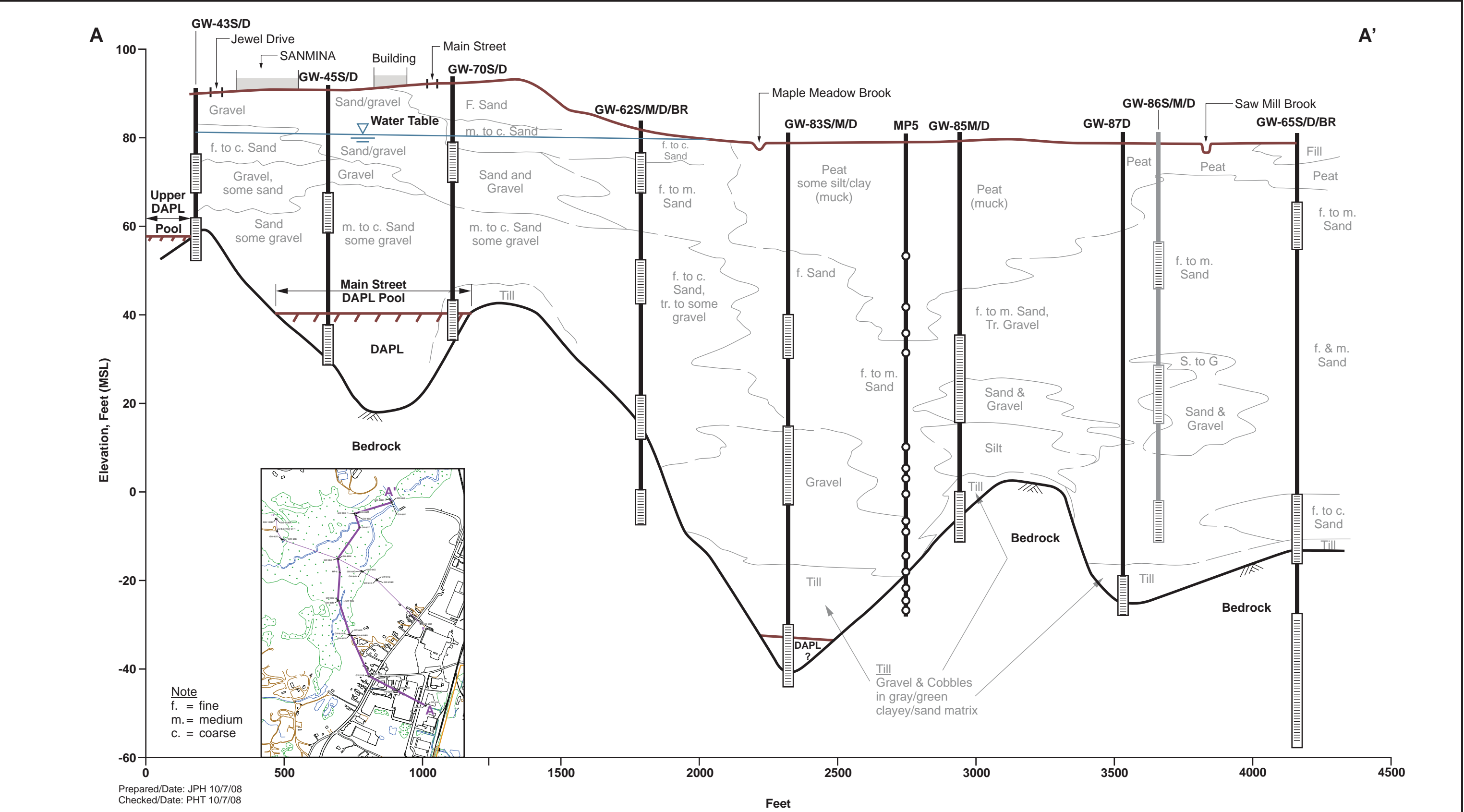
Table 2. Compendium of Identified Data Gaps and Associated Work Plan.

Data Gap Topic	Area(s)	Response Item	USEPA Perceived Data Gap	Phase	Simplified DQOs	Associated Work Plan
DAPL Characterization	Containment Area	14	DAPL extent/characterization Groundwater analytical samples Groundwater levels	II	1. Perceived problems: DAPL/diffuse groundwater presence within bedrock uncertain. Potential for fractures to transmit and/or contain DAPL/diffuse groundwater. 2. Goals: Validate the presence/absence of DAPL/diffuse groundwater within the bedrock and/or fractures, monitor analytical trends. Measure the potentiometric surface, DAPL surface. 3. Info Inputs: analytical concentration data and groundwater levels. 4. Boundaries of Study: Figure 3 5. Analytic Approach: information will be used to refine the CSM and the design for remedial actions.	1. Install multi-port well into deepest point(s) of bedrock surface (contingent on BR surface topography update) 2. Analyze groundwater from overburden vs. weathered bedrock vs. bulk matrix vs. fractured bedrock, characterize maximum vertical extent of contamination.
	Jewel Drive	15	DAPL extent/characterization Groundwater analytical samples Fluid levels	II	1. Perceived problems:DAPL/diffuse groundwater presence within bedrock uncertain. Potential for fractures to transmit and/or contain DAPL/diffuse groundwater. 2. Goals: Validate the presence/absence of DAPL/diffuse groundwater within the bedrock and/or fractures, monitor analytical trends. Measure the potentiometric surface, DAPL surface. 3. Info Inputs: analytical concentration data and groundwater levels. 4. Boundaries of Study: Figure 4 5. Analytic Approach: information will be used to refine the CSM and the design for remedial actions.	1. Replace GW-26 (destroyed) nested monitoring well. 2. Install multi-port wells into deepest point(s) of bedrock surface (contingent on BR surface topography update) 3. Analyze groundwater from overburden vs. weathered bedrock vs. bulk matrix vs. fractured bedrock, characterize maximum vertical extent of contamination.
	Main Street	16	DAPL extent/characterization Groundwater analytical samples Fluid levels	II	1. Perceived problems: DAPL/diffuse groundwater presence and vertical extent within bedrock (bulk matrix vs. fractures) uncertain. Potential for fractures to transmit and/or contain DAPL/diffuse groundwater. 2. Goals: Validate the presence/absence of DAPL/diffuse groundwater within the bedrock and/or fractures, monitor analytical trends. Measure the potentiometric surface, DAPL surface. 3. Info Inputs: analytical concentration data and groundwater levels. 4. Boundaries of Study: Figure 5 5. Analytic Approach: information will be used to refine the CSM and the design for remedial actions.	1. Install multi-port wells into deepest point(s) of bedrock surface (contingent on BR surface topography update). Replace MP-4. 2. Analyze groundwater from overburden vs. weathered bedrock vs. bulk matrix vs. fractured bedrock, characterize maximum vertical extent of contamination.
	Maple Meadow Brook	17	DAPL extent/characterization	II	1. Perceived problems: Large spacing between monitoring points where DAPL could be present. diffusion rates unknown. Potential for long term diffusion from bedrock (if contaminated) into overburden 2. Goals: Identify any additional DAPL pools and/or diffuse groundwater hot spots. 3. Info Inputs: DAPL extent within bedrock, fracture orientation, water-bearing potential, transmissivity, porosity, etc. 4. Boundaries of Study: Figure 6 5. Analytic Approach: locations for borings and MWs to be determined following collection/analysis of AEM survey data. Information will be used to refine the CSM and the design for remedial actions if necessary.	1. AEM survey: may provide data on fluid conductivity contrasts within the overburden and bedrock, possibly detecting DAPL pools. 2. Monitoring well installation to be determined.
Contaminant Extent	North of Olin (GW-413 area)	18	Nature and extent of contaminated groundwater (NDMA focus)	I & II	1. Perceived problem: gap in groundwater monitoring data between GW-413 and CA to the south. 2. Goals: determine extent of bedrockcontamination between CA and GW-413, and overburden and bedrock to the north of GW-413. Identify shallow sheeting fractures as potential for transport mechanism. 3. Info Inputs: COC concentrations and groundwater levels. Depth to weathered bedrock, competent/fractured bedrock, fracture orientation and frequency. 4. Boundaries of Study: Figure 7 5. Analytic Approach: information will be used to refine the CSM	1. Execute geoprobe investigation 2. Collect soil samples in the former production area on the Olin property. 3. Install four nested bedrock monitoring wells. 4. Analyze groundwater from overburden, weathered bedrock, and fractured bedrock, characterize vertical extent of contamination. 5. Install additional nested monitoring wells - locations TBD in Phase II DGWP.
	East of Olin	19	Nature and extent of contaminated groundwater	II	1. Perceived problem: NDMA not bounded to east. Potential for bedrock depressions/fractures to contain contaminated groundwater 2. Goals: determine extent of NDMA contamination to the east of the property line 3. Information Inputs: analytical concentrations and groundwater levels. Depth to bedrock. 4. Boundaries of Study: Figure 8 5. Analytic Approach: information will be used to refine the CSM	1. Install overburden and bedrock monitoring well pairs.



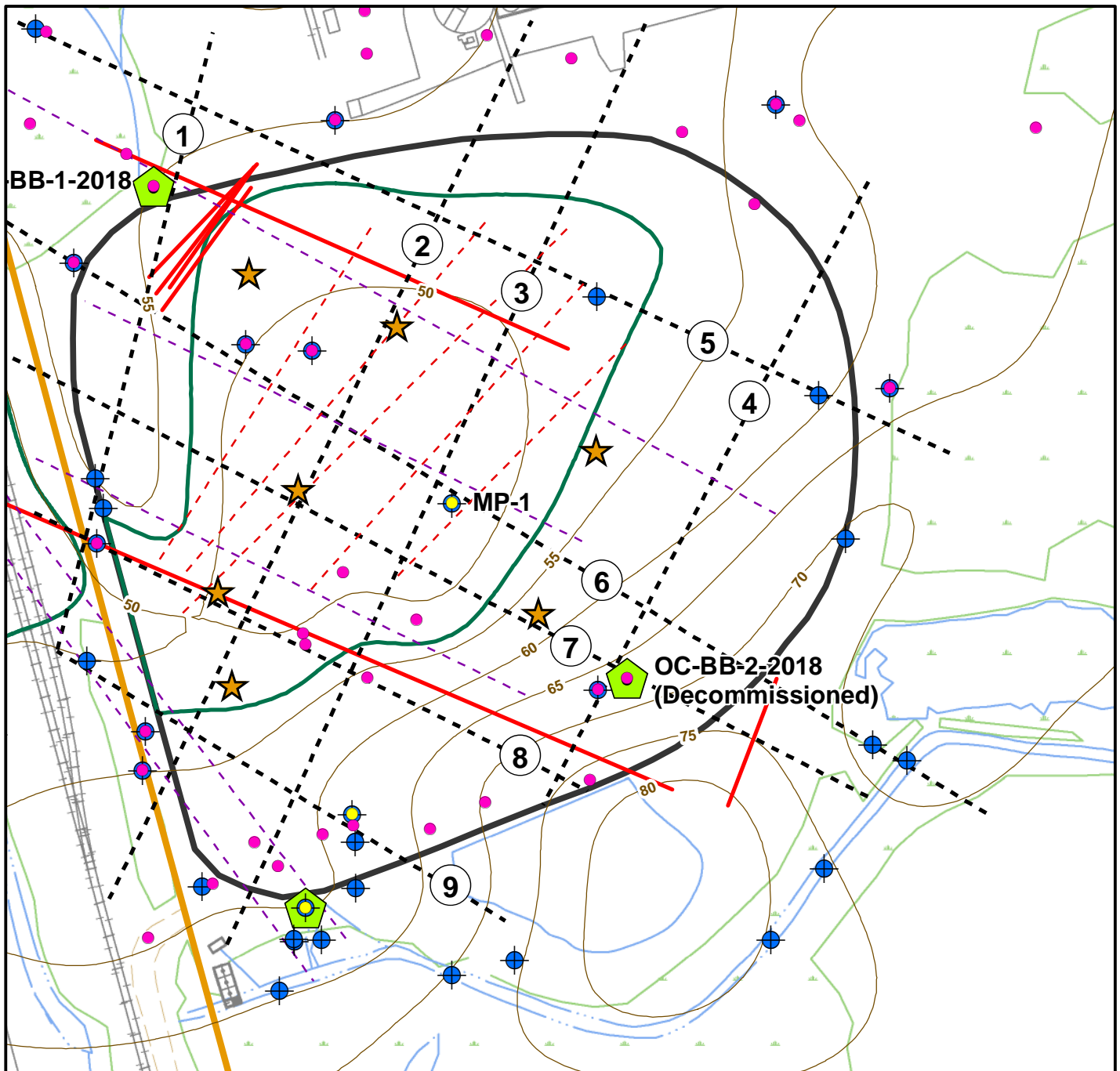


The Wilmington OCSS Site identifying primary USEPA Data Gap Areas.



Conceptual site model describing the distribution of geologic materials in conjunction with groundwater and DAPL elevation.

Figure
2



★ Tentative confirmatory boring

● Existing bedrock well

● Existing boring to bedrock

● Existing S/D groundwater well

● Existing well/bore with geophysical logs

--- Structural fractures, Brandon (2018)

--- Structural fractures, Brandon (2018)

① Proposed lines

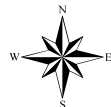
— Inferred faults (USEPA 2018a)

— Bedrock Surface Contours

— 51 Eames St. Property Boundary

— Approximate DAPL Pool Delineation

— Containment Area



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Feet

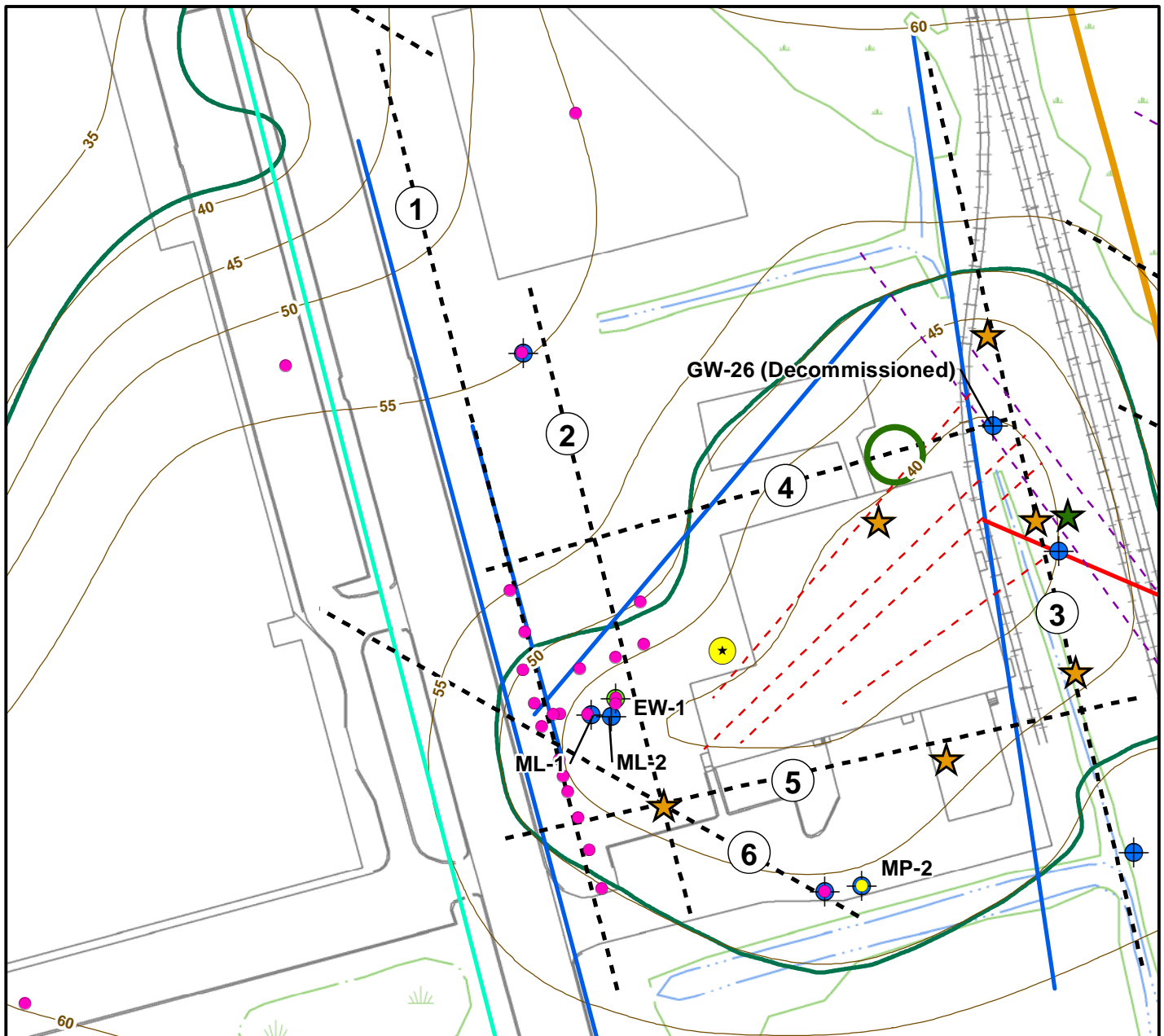


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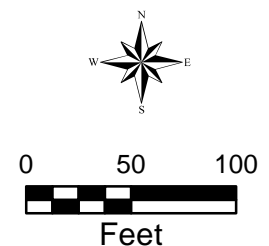
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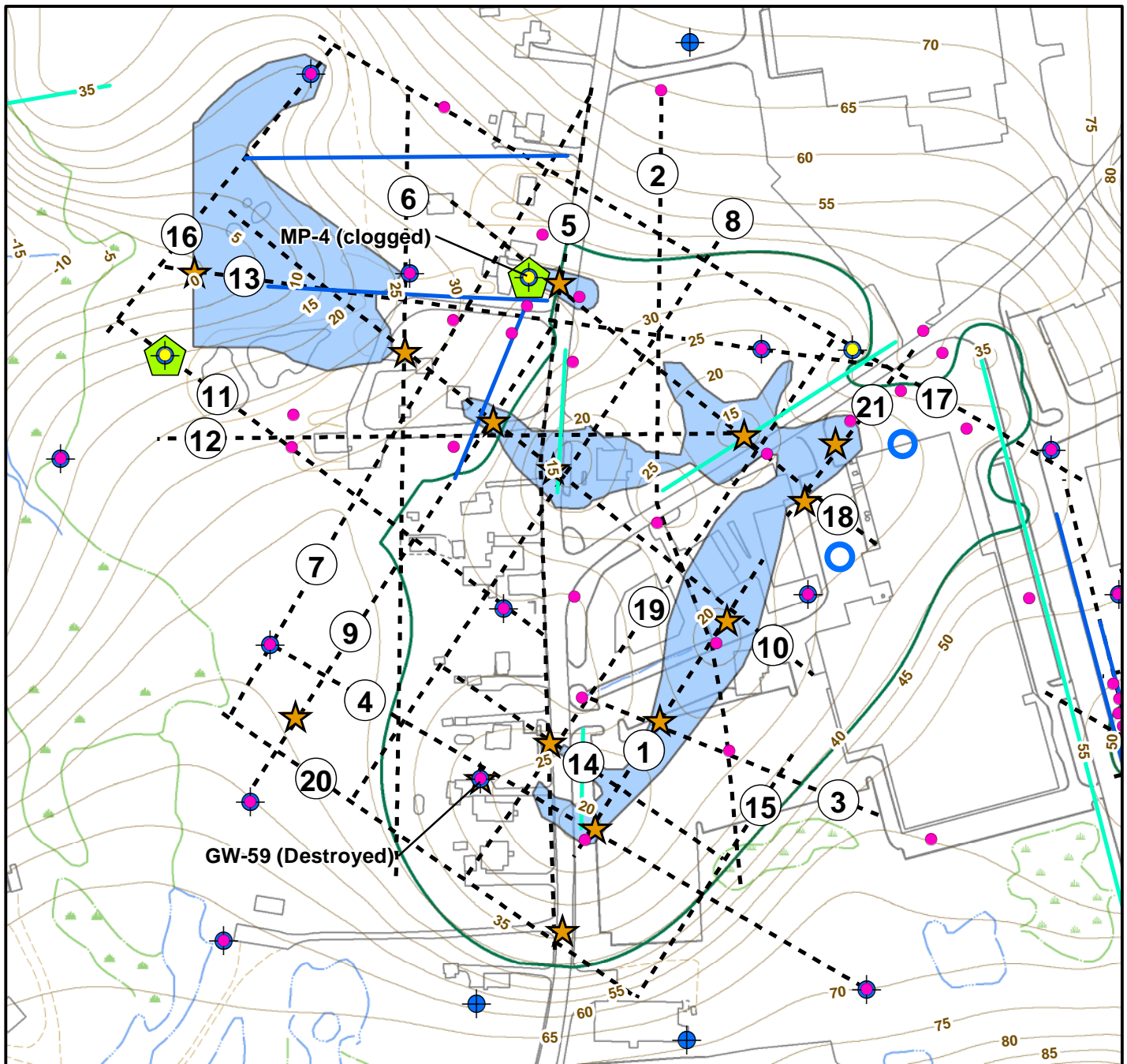
Containment area showing proposed seismic lines
and tentative confirmatory/monitoring wells.

Figure
3

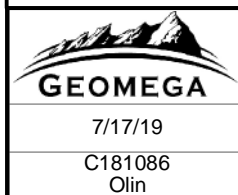
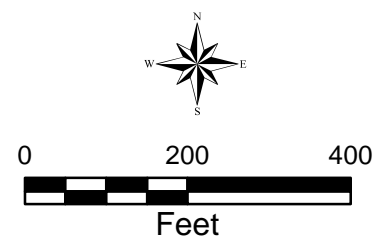


- | | |
|---|--------------------------------------|
| Proposed MP location | Structural fractures, Brandon (2018) |
| Tentative confirmatory boring | Structural fractures, Brandon (2018) |
| Potential angle bore location | Proposed lines |
| Existing bedrock well | Inferred faults (USEPA 2018a) |
| Existing boring to bedrock | Existing seismic refraction lines |
| Existing extraction well | Existing seismic reflection lines |
| Existing S/D groundwater well | Bedrock Surface Contours |
| Tentative geophysics/monitoring well (Phase II) | Approximate DAPL Pool Delineation |
| | 51 Eames St. Property Boundary |



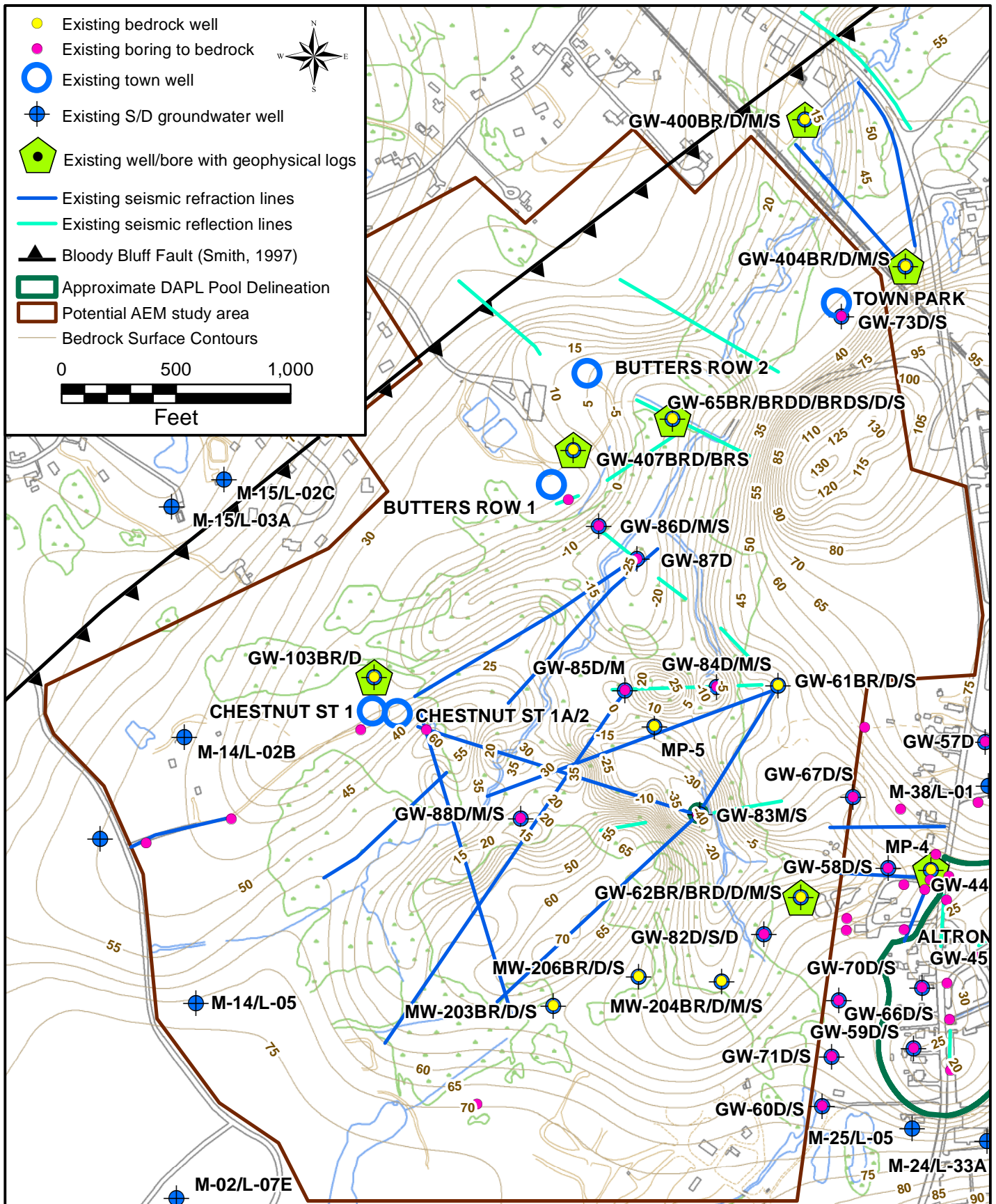


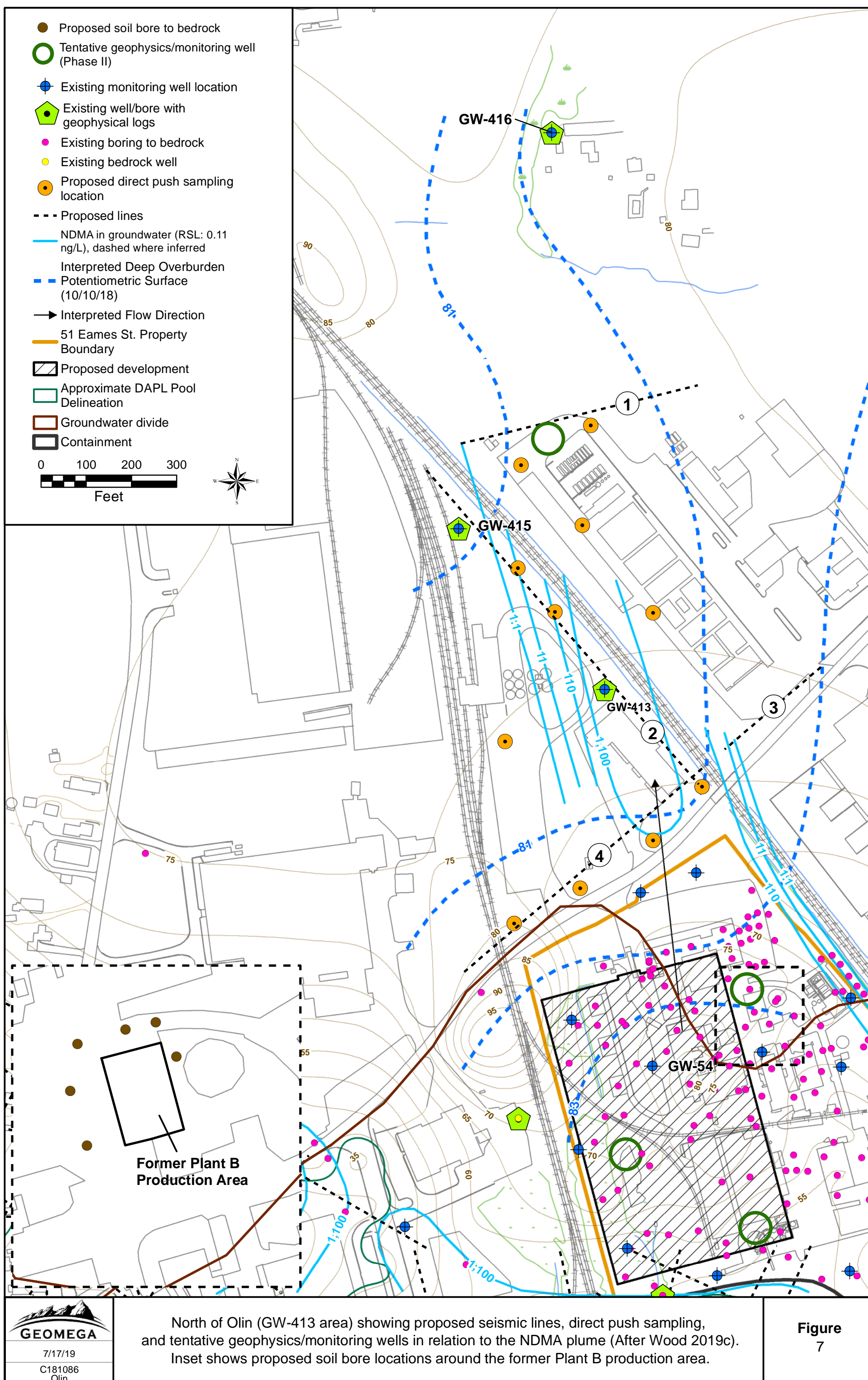
- | | |
|--|--|
| ● Existing bedrock well | ○ Former Sanmina pumping well |
| ● Existing boring to bedrock | — Existing seismic refraction lines |
| ● Existing S/D groundwater well | — Existing seismic reflection lines |
| ★ Tentative confirmatory boring | - (1) - Proposed seismic reflection lines |
| ● Existing well/bore with geophysical logs | — Bedrock Surface Contours |
| | — Approximate DAPL Pool Delineation |
| | — EPA interpreted bedrock surface depression (20') |

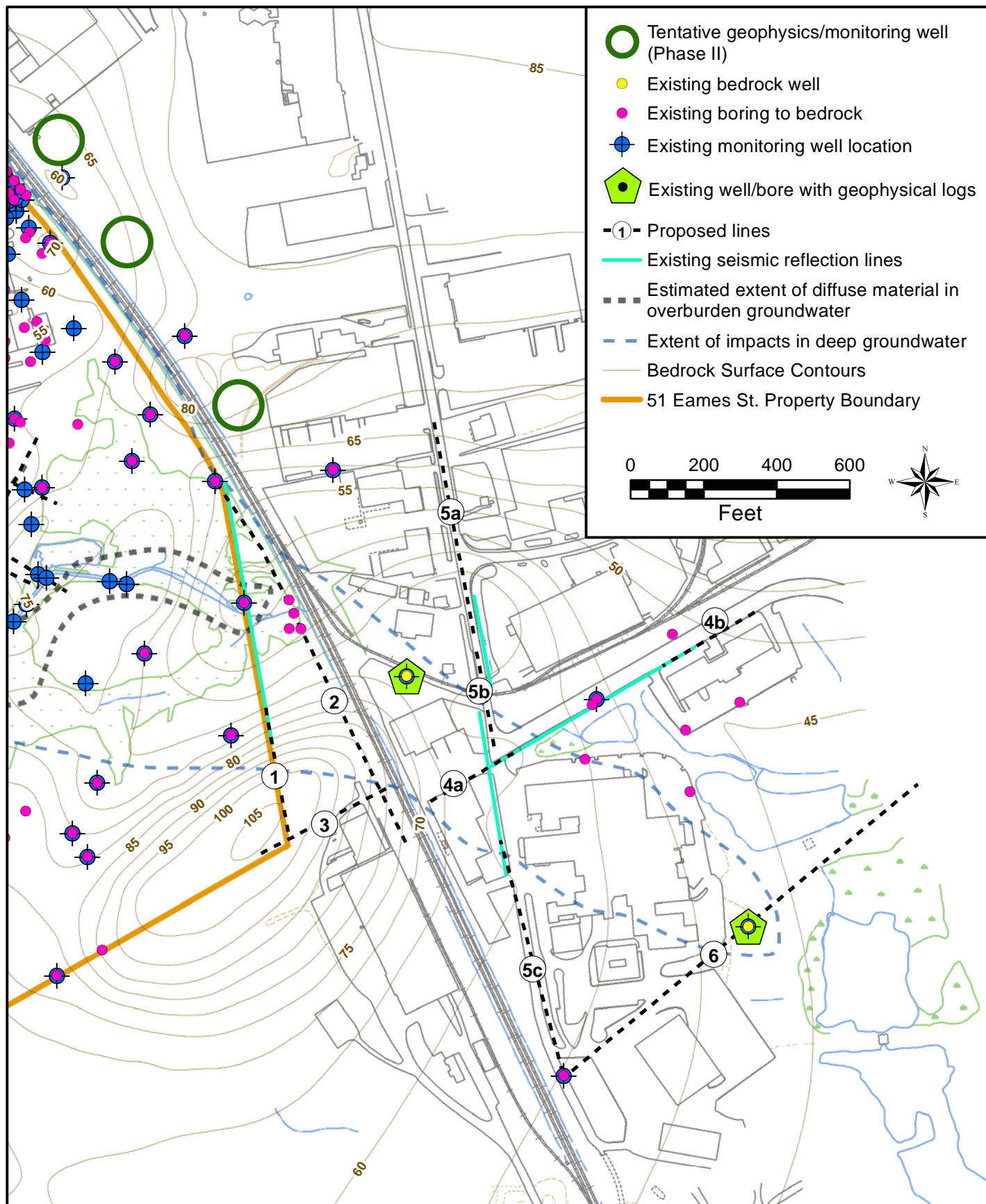


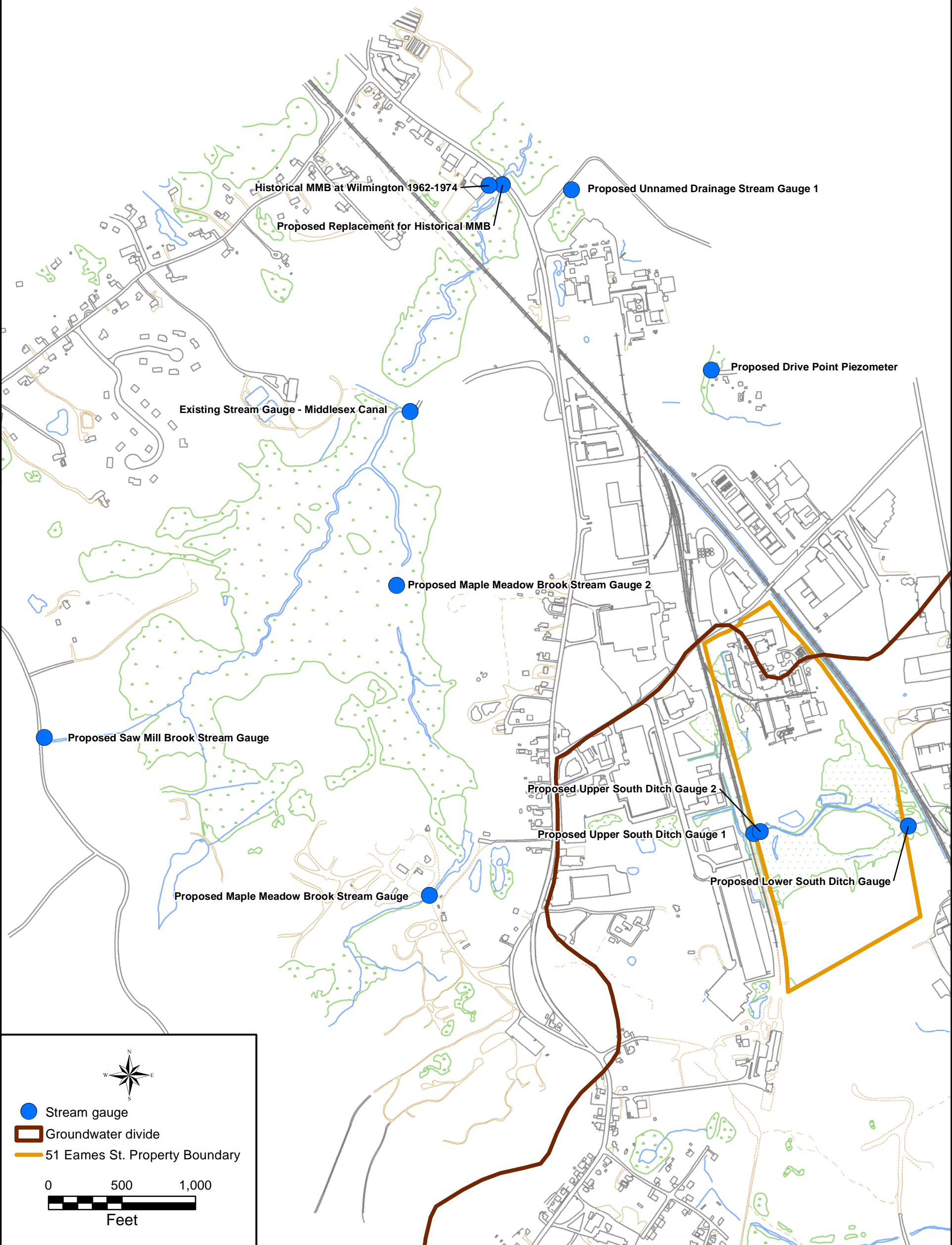
Main Street area showing proposed seismic lines.
At least 12 monitoring wells will be installed
at tentative boring locations during Phase II.

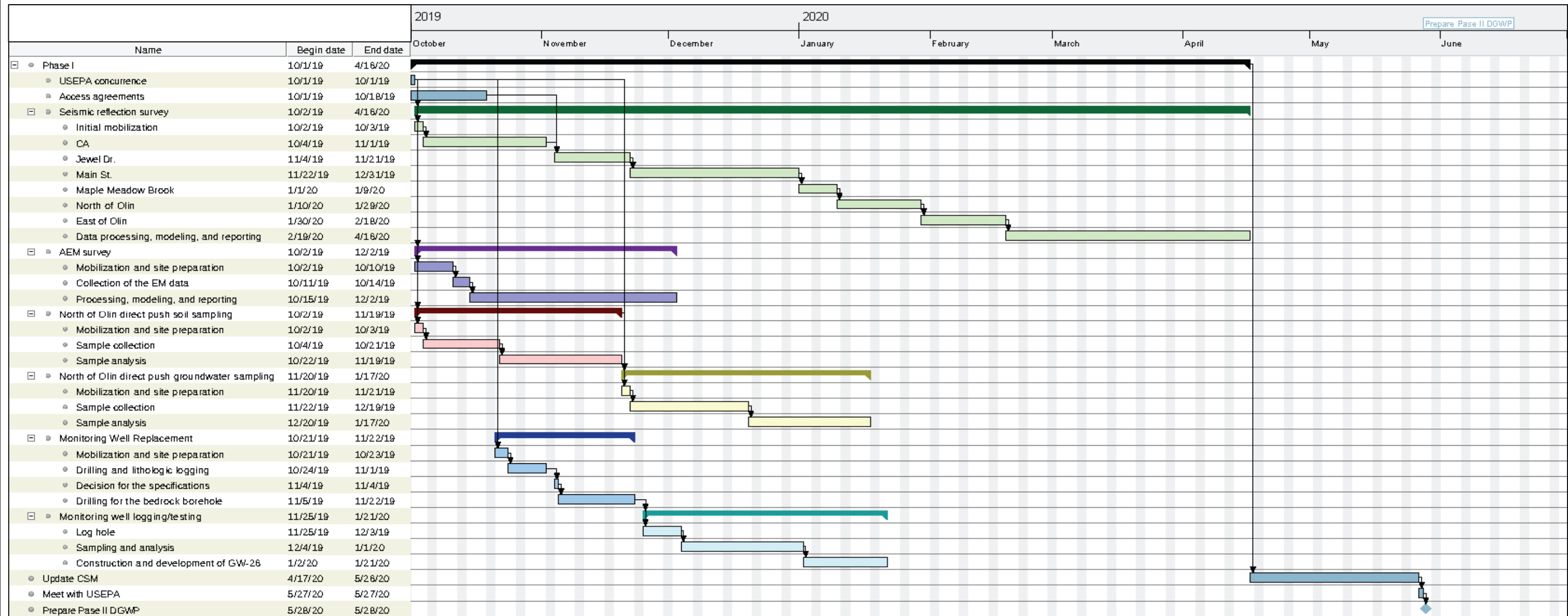
Figure
5











Gantt Chart for the Phase I of the Data Gap Work Plan.

Figure
10